CHARACTERISTICS OF IOWA FINE AGGREGATE

Final Report
for
Research Project MLR-92-6

April 1996

Project Development Division

Iowa Department
of Transportation

Final Report
for
Research Project MLR-92-6

Characteristics of Iowa Fine Aggregate

by

Vernon J. Marks
Research Engineer
515-239-1447
Iowa Department of Transportation
Highway Division
Office of Materials
Ames, Iowa 50010

April 1996

TECHNICAL REPORT TITLE PAGE

1. REPORT NO.	2. REPORT DATE
MLR-92-6	April 1996
3. TITLE AND SUBTITLE	**4. TYPE OF REPORT & PERIOD COVERED**
Characteristics of Iowa Fine Aggregate	Final Report, 8-92 to 4-96
5. AUTHOR(S)	**6. PERFORMING ORGANIZATION ADDRESS**
Vernon J. Marks Research Engineer	Iowa Department of Transportation Materials Department 800 Lincoln Way Ames, Iowa 50010

7. ACKNOWLEDGEMENT OF COOPERATING ORGANIZATIONS

8. ABSTRACT

The objective of this research was to evaluate the quality (angularity, mortar strengths and alkali-silica reactivity) of fine aggregate for Iowa portland cement concrete (pcc) pavements. Sands were obtained from 30 sources representative of fine aggregate across Iowa. The gradation, fineness modulus and mortar strengths were determined for all sands. Angularity was evaluated using a new National Aggregate Association (NAA) flow test. The NAA uncompacted void values are significantly affected by the percent of crushed particles and are a good measure of fine aggregate angularity.

The alkali-silica reactivity of Iowa sands was measured by the ASTM P214 test. By P214 many Iowa sands were identified as being reactive while only two were innocuous. More research is needed on P214 because pavement performance history has shown very little alkali-silica reactivity deterioration of pavement. Six of the sands tested by P214 were evaluated using the Canadian Prism Test. None were identified as being reactive by the Canadian Prism Test.

9. KEY WORDS	10. NO. OF PAGES
Fine aggregate Portland cement concrete Angularity Mortar strength Alkali-silica reactivity Fineness modulus	51

TABLE OF CONTENTS

DISCLAIMER

INTRODUCTION

Aggregates make up 95% of all construction materials. They can have a significant effect on the performance and longevity of the pavement or structure in which they are used. Quite often, aggregate quality, and especially for fine aggregate, is not given sufficient attention. The quality of fine aggregate can have a significant effect on performance and longevity of pavement. New improved tests for evaluating fine aggregate are long overdue.

OBJECTIVE

The objective of this research is to evaluate the quality of fine aggregates representative of the sands used in Iowa pavements. This evaluation will include gradation, angularity, mortar strengths and potential for alkali silica reactivity.

SELECTION OF SANDS

The 30 fine aggregate sources to be evaluated were selected by the Iowa DOT Chief Geologist to be representative of those used in Iowa. The location of those sources is shown in Figure 1. The samples obtained were as produced for "fine aggregate for concrete" (Section 4110 of the Iowa DOT Standard Specifications). In most cases, the producers crush some oversize material, so some crushed material is included in the fine aggregate. The composition of fine aggregate varies across the state, but many contain substantial carbonate particles, ranging from 0 to 40% depending on the source. An x-ray diffraction petrographic analysis (Figure 2 & 3) is being used to determine the composition of Iowa sands. Petrographic analysis was not conducted on all 30 sands selected for this research.

GRADATION AND FINENESS MODULUS

All aggregate samples received by the central laboratory are assigned a laboratory number such as AAS2-0345. The AAS2 is common for all sands received in 1992. The AAS2 will be dropped and the laboratory number will be given as a number between 285 and 378, each representing one of the 30 sands. The source, county and laboratory number of the 30 sands are given in Table 1.

The gradations of the 30 sands in percent passing are given in Table 2. The fineness modulus given in Table 1 was determined by ASTM C136 (Appendix A).

MORTAR STRENGTH

The Iowa DOT has specified a mortar strength for "fine aggregate for concrete" since 1937. It has been modified some over the years and the specification requirements have been altered accordingly. Currently, the Standard Specifications require a mortar strength not less than 1.5 times the strength of mortar in which standard sand was used when tested by Iowa DOT Materials Laboratory Test Method 212 (Appendix B). The mortar strengths for the 30 sands are given in Table 1.

ANGULARITY

Angularity is a very important characteristic of aggregate, but no real good test had been available to measure angularity. The National Aggregate Association (NAA) has developed a new flow test (Appendix C) to measure angularity. It is a very simple test where the fine

aggregate is allowed to flow from a funnel, fall 114 mm and fill a 100 cm^3 cylindrical measure. The angularity is measured by the percent voids in the uncompacted material. Methods A, B and C of the flow test indicate the gradation of the test sample. Only Method A and Method C (as received) were used in this research. The Method C gradation is given in Table 2 and the Method A gradation is:

Sieve Size			
Passing	Retained on		Mass, g
#8	#16		44
#16	#30		57
#30	#50		72
#50	#100		17
		Total	190

The NAA flow test was also used with the gradation specified for the P214 alkali-silica reaction test. That gradation is:

Sieve Size			
Passing	Retained on	Mass, %	Mass, g
#4	#8	10	19
#8	#16	25	47.5
#16	#30	25	47.5
#30	#50	25	47.5
#50	#100	15	28.5
		Total	190.0

The percent void results of the P214 grading are also given in Table 1.

Linear correlations were obtained between all three of the gradations: Method A, Method C and Method P214. The Coefficient of Determination, R^2 between Method A and Method C was 0.33. The R^2 for Method A and Method P214 was 0.46 and the R^2 for Method C and Method P214 was 0.44. These three coefficients of determination shows there is a relationship, but not a strong correlation.

In regard to angularity, one goal of this project was to determine the variation in angularity across the state. That data is given in Table 1 with uncompacted voids ranging from 35.52 to 42.37 (Method A). The lowest uncompacted void content was for the fine aggregate from the Bellevue Pit in Jackson County. This pit is near the Mississippi River. Another unique characteristic is that the production operation does not use a crusher so there is no crushed particles in the final product. There is substantial oversize available.

The Bellevue pit appeared to present an excellent opportunity to evaluate the effect of crushed particles on the uncompacted void content. Additional samples of both the fine aggregate and the oversized material were obtained. The oversized material was crushed through a laboratory jaw crusher numerous times to produce a 100% crushed manufactured sand. This manufactured sand was blended with the Bellevue plant production to yield Method A gradations with 0, 2.5, 5.0, 10, 15, 20, 25 and 100% crushed material. The graphical plot (Figure 4) shows a relatively linear increase in void content from 36 to 50% as the crushed material increases from 0 to 70%. This data shows that the amount of crushed material has a significant effect on the NAA uncompacted void content.

Some states had reported that as sand was carried down a river the uncompacted void content decreased. The reasoning was that it was more angular upstream and it was polished and rounded as it traveled downstream. Fine aggregate sources were selected on the Des Moines and Cedar Rivers (Figure 1) to determine if upstream sand was more angular. The Method A uncompacted void values for sources on the Des Moines River (and tributaries) from upstream to downstream are:

D1	285	Van Meter/ Dallas	40.46
D2	333	EDM#2/Polk	41.03
D3	296	Kammerick/Marion	40.45
D4	297	Hoffman/Wapello	39.47
D5	286	Vincennes/Lee	41.29

The Method A uncompacted void values for sources on the Cedar River (and tributaries) from upstream to downstream are:

C1A	368	Nashua/Chickasaw	39.59
C1B	349	Randall Transit/Worth	41.67
C2	371	Livingston/Black Hawk	39.59
C3	356	Baird #2/Linn	41.26
C4	346	Sharpliss/Cedar	39.21

As can be seen from these two tabulations, there is not a trend that shows a change from more to less angularity for sources from upstream to those downstream. These samples were "as produced" fine aggregate. The uncompacted voids might be more dependent on how much oversized material is crushed. For this analysis, it would have been better to have obtained samples of the sands before processing. This might be done at a future time.

ALKALI-SILICA REACTIVITY

The Iowa DOT has not recognized a significant problem of alkali-silica reaction deterioration. There is, however, some portland cement concrete deterioration in Iowa that exhibits a crack pattern very similar to that generally attributed to alkali-silica reaction.

ASTM P214 Test

The Portland Cement Association (PCA) has developed a "Guide Specification for Concrete Subject to Alkali-Silica Reactions" March 1995. This guide specification proposes the use of ASTM C1260 (similar to P214 but modified slightly) for initial evaluation of aggregate. If C1260 identifies an aggregate as potentially reactive the guide specification proposes the use of the Canadian Prism Test CSA A23.2-14A (now ASTM C1293) to determine if an aggregate is or is not reactive. An ASTM C-9 proposal P214 describes "Proposed Test Method for Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction" (Appendix D). When these aggregates were evaluated in 1992, this was a new 16 day test to evaluate the alkali-silica reaction potential of an aggregate. Mortar bars made with the selected aggregate are soaked in a 1N solution of sodium hydroxide (NaOH) at 176°F. The growths obtained from this test on the 30 sands are given in Table 3. The P214 test states that "when the mean expansion of the test specimens exceeds 0.20% at 16 days from casting, it is indicative of potentially deleterious expansion." Also, "less than 0.10%---is indicative of innocuous behavior." And "above 0.10% and less than 0.20%---are not as yet conclusive."

Based on these criteria, 11 of the 30 sands were reactive, 17 were inconclusive and two were innocuous (Table 3). In general, the P214 reactive sands are in the western part of Iowa, the inconclusive sands are in eastern Iowa and the two innocuous sands are in south central Iowa. Many of the "reactive" sands have been used in pcc pavement for years with good performance.

Canadian Prism Test

A decision was made to select six of the 30 sands to conduct Canadian Prism Testing. The selection included the two sands from the "reactive" group with the greatest P214 expansion (Emmetsburg 0.32% and Sankey 0.33%), two from the "inconclusive" group (McCausland 0.17% and Colfax 0.18%) and the two "innocuous sands (Cincinnati 0.06% and Kammerick 0.10%). These were tested by both the Iowa DOT and Lafarge Canada Inc., both with and without a Class C fly ash.

A Davenport Lafarge Type I cement was used to evaluate the six Iowa sands by the Canadian Prism Test (Appendix E). The coarse aggregate was a pyritic dolomite from the Nelson Quarry in Canada. The Class C fly ash was from the Chillicothe-Ottumwa power plant.

The Iowa DOT subjected them to the test for 12 months while Lafarge Canada, Inc. continued the test for 24 months. The expansions for the six sands are given in Table 4. If expansions exceed 0.04%, the test would identify the aggregate to be alkali-silica reactive. The Emmetsburg with no fly ash yielded the greatest expansion, but only 0.031%. This is

well below the 0.04% maximum. Therefore, we do not believe any of the six sands are alkali-silica reactive and very likely none of the 30 sands are alkali-silica reactive.

COMPARISON OF TESTS

The NAA uncompacted void angularity values were compared to the mortar strengths. The Method A uncompacted voids yielded a coefficient of determination, R^2, of 0.13 when compared to mortar strengths. This is a very poor correlation indicating little relationship. The Method C "as received" gradation yielded an R^2 of 0.42 when compared to mortar strength. This shows a definite relationship, but not a real strong correlation. When the P214 gradation was compared to mortar strength, it yielded an R^2 of only 0.11 indicating very little relationship.

The coefficient of determination, R^2, for mortar strength compared to fineness modulus was only 0.29, some relationship, but a very poor correlation.

CONCLUSIONS

This research on characteristics of Iowa fine aggregate for concrete supports the following conclusions:

1. The NAA uncompacted void test is a relatively simple but good measure of fine aggregate angularity.
2. The percent of crushed particles in the fine aggregate has a significant effect on the NAA uncompacted void values.

3. Although there is a weak relationship, there is a poor correlation of mortar strength with fineness modulus and NAA uncompacted voids.

4. The P214 alkali-silica reactivity test indicates that many Iowa sands are potentially reactive and only a few are innocuous.

5. The Canadian Prism Test did not identity Iowa fine aggregate as alkali-silica reactive.

6. Based on this limited research, the ASTM P214 does not appear to be a good test to determine potential alkali-silica reactivity of Iowa aggregate.

ACKNOWLEDGEMENTS

Champ Narotam provided the direction and supervision of the testing of the fine aggregate for this research. Wayne Strum and Steve Kennedy of the aggregate laboratory conducted the gradation testing and NAA flow tests. The mortar strength and alkali-silica reactivity testing was conducted by Ralph Kalsem and the Concrete Section. The Iowa DOT also extends appreciation to Bob Suderman and Lafarge Canada for conducting Canadian Prism testing on Iowa sands.

TABLE TITLES

TABLE 1
Angularity Void Content, Fineness Modulus and Mortar Strength

MLR-92-6

CHARACTERISTICS OF IOWA SAND		METHOD A *		METHOD C **		METHOD P-214 ***		fineness	MORTAR
SOURCE/COUNTY	SAMPLE N (S-XXX)	W.CONST SP.GR UNCOMP VOIDS	WITH SP.GR. UNCOMP. VOIDS	W CONST. SP. GR UNCOMP. VOIDS	WITH SP. GR UNCOMP. VOIDS	W CONST. SP. GR UNCOMP. VOIDS	WITH SP. GR UNCOMP. VOIDS	modulus	STR.
VAN METER/DALLAS	285	40.233	40.458	38.749	38.979	37.918	37.684	2.74	1.8
VINCENNES/LEE	286	40.842	41.285	39.054	39.510	38.717	38.255	2.71	1.6
KAMMERICK/MARION	296	40.005	40.454	38.977	39.435	37.622	37.151	2.97	1.7
HOFFMAN/WAPELLO	297	39.700	39.472	37.380	37.142	37.715	37.950	2.86	1.7
COLFAX/JASPER	330	39.510	39.963	36.276	36.754	37.886	37.418	3.56	2.0
MARSHALLTOWN/MARSHAL	331	40.423	40.869	38.521	38.981	38.264	37.798	2.92	1.8
WRIGHT/GREENE	332	41.793	41.793	38.635	38.635	39.054	39.054	2.96	1.8
EDM #2/POLK	333	41.032	41.032	40.765	40.765	39.320	39.320	2.70	1.6
GENEVA/FRANKLIN	334	41.070	41.291	36.276	36.516	38.108	37.874	3.33	1.9
BELLEVUE/JACKSON	344	34.793	35.523	34.793	35.523	36.501	35.782	2.88	1.8
MCCAUSLAND/SCOTT	345	38.863	39.093	36.695	36.933	36.478	36.238	3.04	1.8
SHARPLISS/CEDAR	346	39.206	39.206	37.494	37.494	36.428	36.428	2.85	1.6
CINCINNATI/APPANOOSE	347	41.717	42.369	38.825	39.510	40.450	39.776	3.03	1.7
RANDALL TRANSIT/WORTH	349	41.450	41.670	37.836	38.070	39.358	39.130	3.35	1.7
SANKEY/HANCOCK	350	40.918	40.918	39.814	39.814	38.635	38.635	2.62	1.5
CROFT/WEBSTER	351	40.613	40.613	38.901	38.901	36.733	36.733	3.09	1.7
BAIRD #2/LINN	356	41.260	41.260	41.260	41.260	40.613	40.613	2.68	1.6
SACTON-LAKEVIEW/SAC	358	41.564	42.002	38.369	38.830	38.679	38.217	3.20	1.6
AVOCA/POTTAWATTAMIE	362	41.374	41.374	38.293	38.293	38.939	38.939	2.92	1.7
BARRY/HARRISON	363	37.988	38.221	39.548	39.775	39.169	38.939	3.07	1.8
SHENANDOAH/PAGE	364	40.727	40.277	38.749	38.283	38.590	39.054	2.88	1.7
OREAPOLIS/CASS, NEBR.	365	38.521	37.817	35.858	35.123	35.893	36.619	2.69	1.9
DECORAH/WINNESHIEK	366	40.499	40.723	37.836	38.070	38.563	38.331	3.22	1.8
PAPE/FAYETTE	367	40.880	40.880	38.407	38.407	37.684	37.684	3.25	1.7
NASHUA/CHICKASAW	368	39.358	39.586	36.010	36.251	37.236	36.999	3.08	1.9
LIVINGSTON/BLACK HAWK	371	39.586	39.586	38.369	38.369	37.075	37.075	2.66	1.7
LOGAN/DELAWARE	372	41.222	41.222	39.700	39.700	38.939	38.939	2.67	1.6
EMMETSBURG/PALO ALTO	376	41.222	41.662	38.407	38.868	39.321	38.863	2.97	1.7
OCHEYEDAN/OSCEOLA	377	41.412	41.632	38.140	38.373	40.495	40.271	3.38	1.8
HAWARDEN-NORTH/SIOUX	378	39.320	39.774	38.939	39.397	38.679	38.217	3.40	1.8

* method A used constant sp.gr. 2.65
method A used sp.gr. with the sourse sp.gr.

** method C used constant sp.gr. 2.65
method C used sp.gr. with the sourse sp.gr.

*** method P-214 used constant sp.gr. 2.65
method P-214 used sp.gr. with the sourse sp.gr.

3/16/93
Steve L.

TABLE 2

Fine Aggregate Gradations
as Received - Percent Passing
Identified by Laboratory Number

Sieve Size	285	286	296	297	330	331	332	333	334	344	345	346	347	349	350	351	356	358	362	363	364	365	366	367	368	371	372	376	377	378
3/8	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
#4	99	98	99	96	96	98	100	99	97	98	99	96	94	96	100	98	100	98	98	100	94	100	92	96	96	98	98	100	96	100
#8	87	91	91	86	76	89	88	94	78	86	94	88	82	77	96	85	94	84	87	89	87	95	81	85	81	90	92	90	77	88
#16	71	76	70	73	48	72	65	77	55	70	72	74	66	53	77	65	80	64	68	64	72	72	64	64	62	76	79	62	52	52
#30	48	49	36	48	21	41	39	46	30	45	23	46	43	30	50	34	48	36	43	33	45	45	34	29	38	52	52	36	27	17
#50	18	14	6.4	10	2.7	7.3	11	12	6.2	12	7.9	9.5	11	7.9	14	6.8	8.6	7.4	11	6.4	12	17	5.8	1.3	13	16	11	14	7.5	2.7
#100	2.7	1.3	1.1	0.5	0.3	0.5	0.9	1.6	0.6	1.4	0.4	1.2	1.1	1.2	1.4	1.9	1.1	1.0	1.2	0.7	1.7	2.2	0.6	0.4	1.6	1.7	0.8	1.4	1.7	0.4
#200	1.2	0.6	0.7	0.1	0.2	0.3	0.3	1.0	0.3	0.2	0.1	0.7	0.4	0.7	0.6	1.3	0.3	0.6	0.5	0.4	1.2	0.6	0.4	0.3	0.7	0.5	0.4	0.3	1.1	0.2

TABLE 3

MLR–92–6
CHARACTERISTICS OF IOWA SANDS
ASTM P–214 TESTING

MIX NO.	SAND SOURCE	PERCENT EXPANSION
13	CINCINNATI	0.06
3	KAMMERICK	0.10
23	DECORAH	0.12
6	MARSHALLTOWN	0.12
4	HOFFMAN	0.12
9	GENEVA	0.13
10	BELLEVUE	0.13
21	SHENANDOAH	0.13
27	LOGAN	0.14
12	SHARPLISS	0.15
24	PAPE	0.15
14	RANDALL TRANSIT	0.16
16	BAIRD #2	0.17
11	MCCAUSLAND	0.17
25	NASHUA	0.17
29	OCHEYEDAN	0.18
5	COLFAX	0.18
26	LIVINGSTON	0.18
30	HAWARDEN–NORTH	0.19
1	VAN METER	0.20
2	VINCENNES	0.22
18	SACTON–LAKEVIEW	0.22
20	BARRY	0.23
17	CROFT	0.23
19	AVOCA	0.23
7	WRIGHT	0.24
22	OREAPOLIS	0.27
8	EDM #2	0.28
28	EMMETSBURG	0.32
15	SANKEY	0.33

TABLE 4
A Summary of
Canadian Prism Test Expansions

SAND SOURCE	PERCENT EXPANSION					
	IOWA DOT		LAFARGE			
	12 MONTH		12 MONTH		24 MONTH	
	NO FLY ASH	WITH FLY ASH	NO FLY ASH	WITH FLY ASH	NO FLY ASH	WITH FLY ASH
Cincinnati	0.025	0.025	0.018	0.017	0.024	0.024
Kammerick	0.023	0.024	0.018	0.021	0.023	0.026
McCausland	0.014	0.024	0.017	0.022	0.023	0.028
Colfax	0.022	0.026	0.016	0.021	0.022	0.025
Emmetsburg	0.020	0.029	0.024	0.018	0.031	0.024
Sankey	0.027	0.026	0.023	0.021	0.028	0.027

FIGURE CAPTIONS

1. Sources of Fine Aggregate
2. Cordova Pit XRD Fine Aggregate Analysis
3. Conn Pitt XRD Fine Aggregate Analyses
4. The Effect of Crushed Particles on the NAA Uncompacted Void Content

Figure 1 - Sources of Fine Aggregate

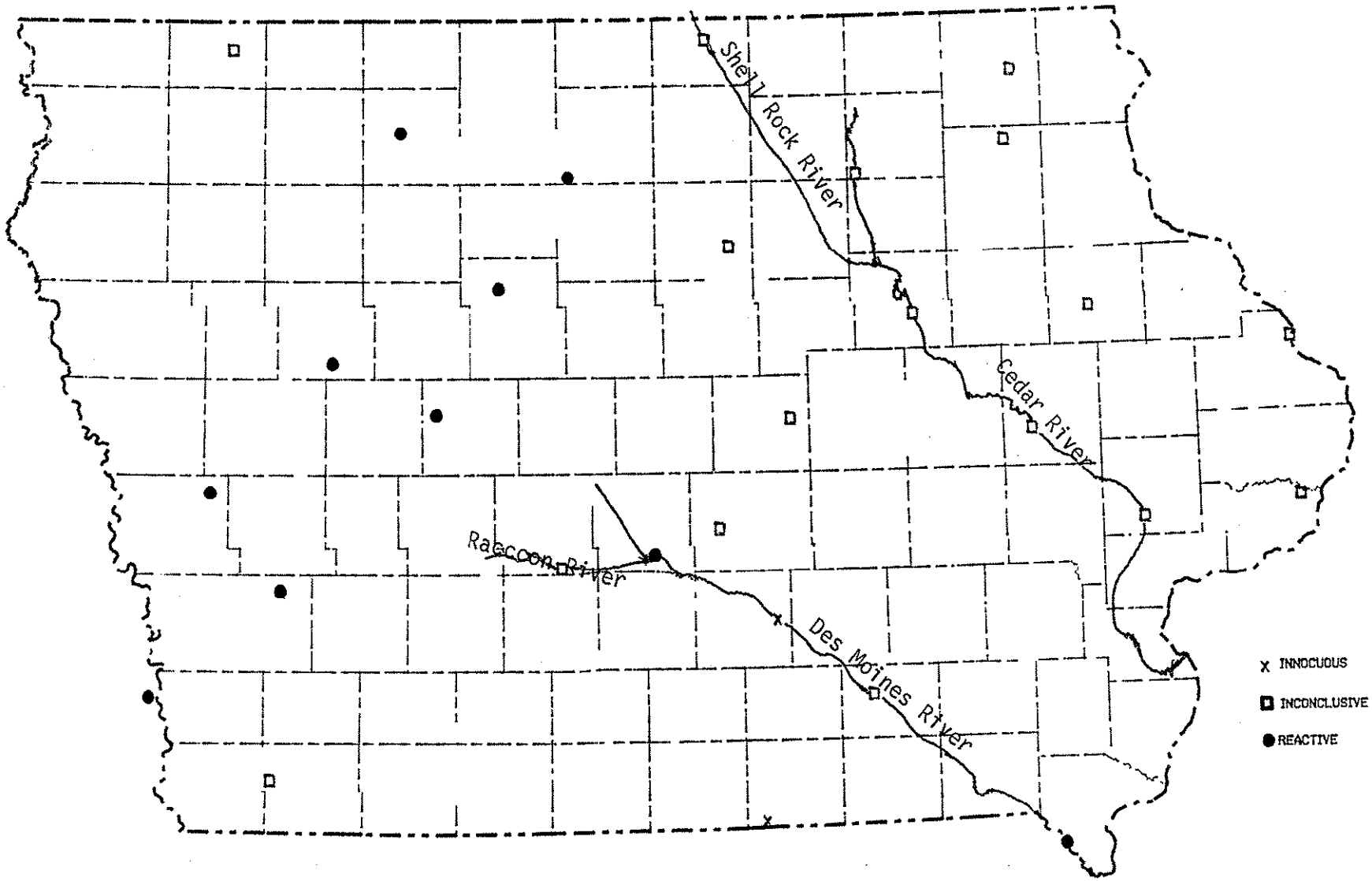
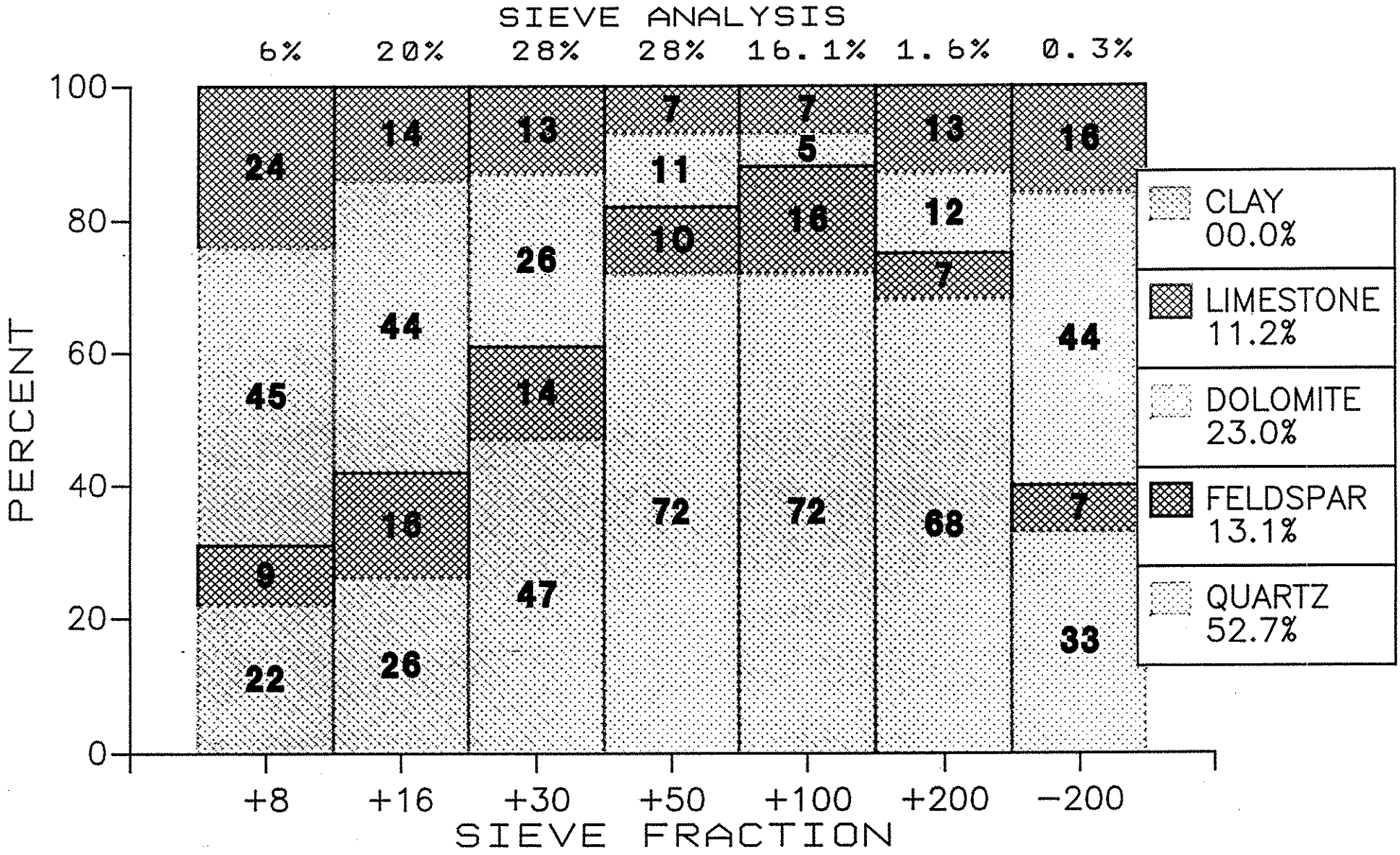


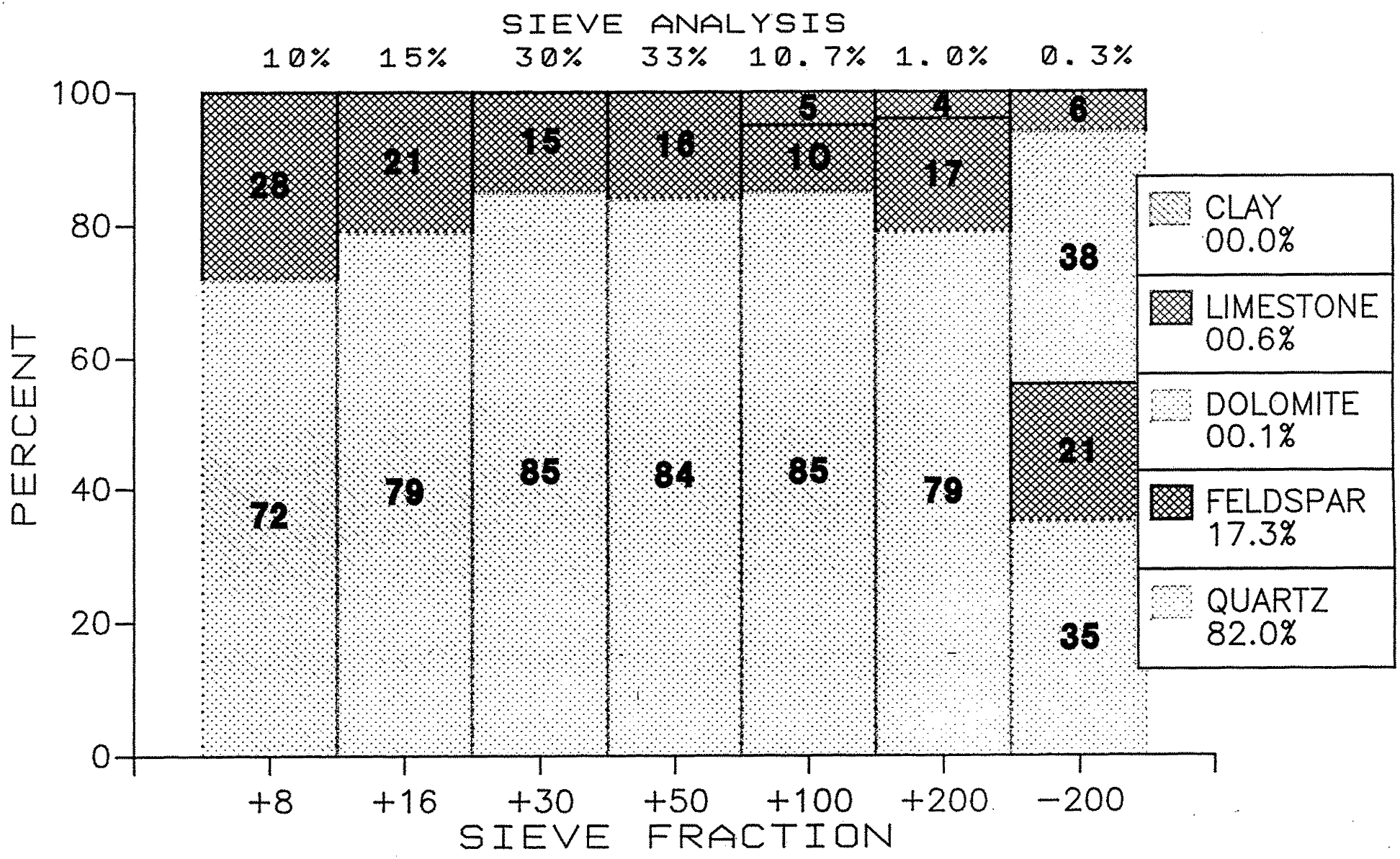
Figure 2 **CONN PIT**

XRD FINE AGGREGATE ANALYSES



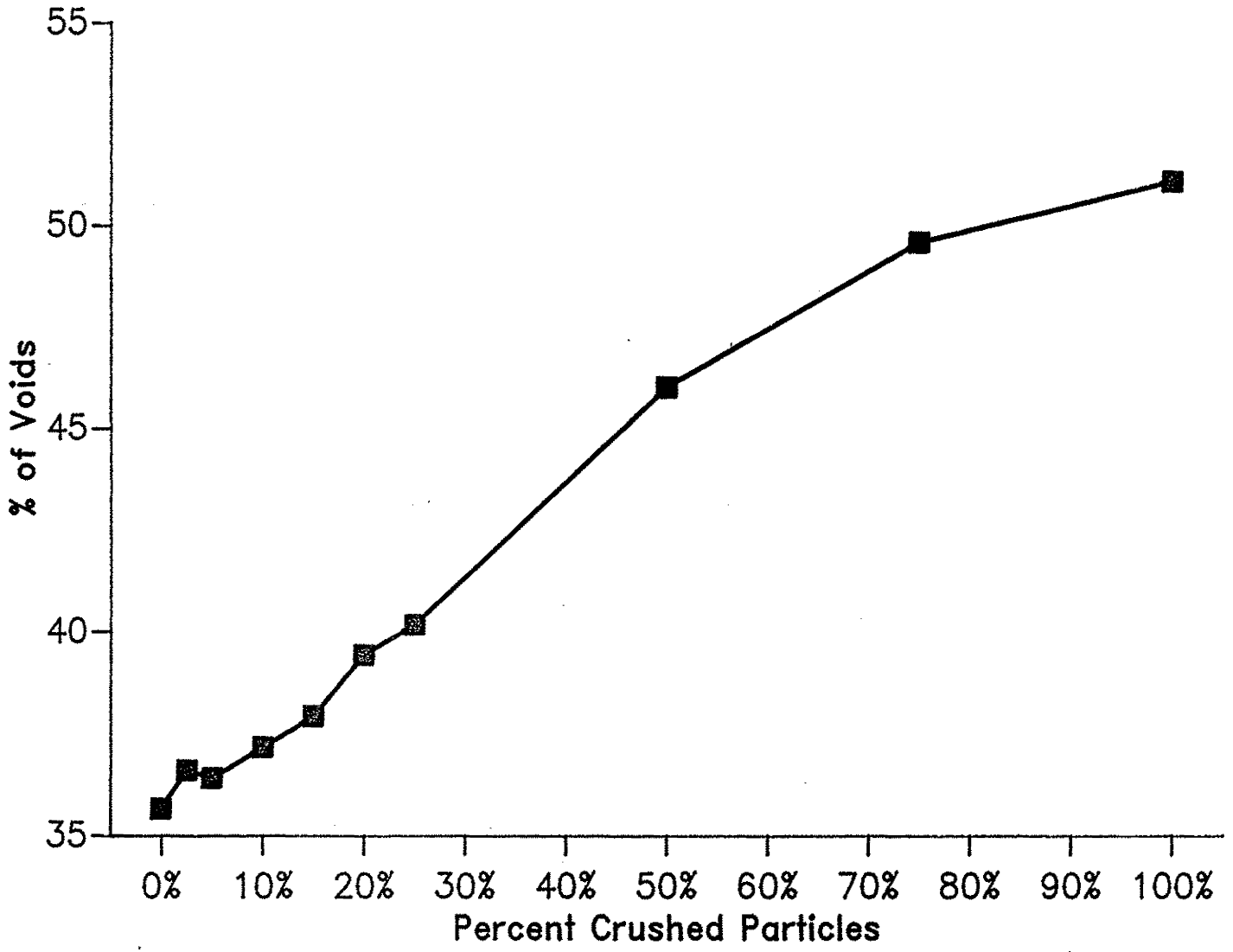
SAVECODE FAXRD007

Figure 3 **CORDOVA PIT**
XRD FINE AGGREGATE ANALYSES



SAVECODE FAXRD006

Figure 4. The Effect of Crushed Particles on the NAA Uncompacted Void Content



Appendix A
ASTM C136 Standard Test Method for Sieve Analysis
of Fine and Coarse Aggregates

Designation: C 136 – 92

Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates[1]

This standard is issued under the fixed designation C 136; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This test method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

1.2 Some specifications for aggregates which reference this method contain grading requirements including both coarse and fine fractions. Instructions are included for sieve analysis of such aggregates.

1.3 The values stated in acceptable metric units (SI units and units specifically approved in ASTM E 380 for use with SI units) are to be regarded as the standard. The values in parentheses are provided for information purposes only.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 117 Test Method for Materials Finer Than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates[3]

C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials[3]

C 702 Practice for Reducing Field Samples of Aggregate to Testing Size[3]

D 75 Practice for Sampling Aggregates[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

E 380 Practice For Use of the International System of Units (SI) (the Modernized Metric System)[5]

2.2 *AASHTO Standard:*

AASHTO No. T 27 Sieve Analysis of Fine and Coarse Aggregates[6]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, refer to Terminology C 125.

4. Summary of Test Method

4.1 A weighed sample of dry aggregate is separated through a series of sieves of progressively smaller openings for determination of particle size distribution.

5. Significance and Use

5.1 This test method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

5.2 Accurate determination of material finer than the 75-μm (No. 200) sieve cannot be achieved by use of this method alone. Test Method C 117 for material finer than 75-μm sieve by washing should be employed.

6. Apparatus

6.1 *Balances*—Balances or scales used in testing fine and coarse aggregate shall have readability and accuracy as follows:

6.1.1 For fine aggregate, readable to 0.1 g and accurate to 0.1 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

6.1.2 For coarse aggregate, or mixtures of fine and coarse aggregate, readable and accurate to 0.5 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

6.2 *Sieves*—The sieves shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. The sieves shall conform to Specification E 11. Sieves with openings larger than 125 mm (5 in.) shall have a permissible variation in average opening of ±2 % and shall have a nominal wire diameter of 8.0 mm (5/16 in.) or larger.

NOTE 1—It is recommended that sieves mounted in frames larger than standard 203-mm (8 in.) diameter frames be used for testing coarse aggregate.

6.3 *Mechanical Sieve Shaker*—A mechanical sieve shaker, if used, shall impart a vertical, or lateral and vertical, motion to the sieve, causing the particles thereon to bounce and turn so as to present different orientations to the sieving

[1] This test method is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Normal Weight Aggregates.

Current edition approved Nov. 15, 1992. Published January 1993. Originally published as C 136 – 38 T. Last previous edition C 136 – 84a.

[2] *Annual Book of ASTM Standards*, Vols 04.02 and 04.03.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 14.02. Excerpts in all volumes.

[6] Available from American Association of State Highway and Transportation Officials, 444 North Capitol St. N.W., Suite 225, Washington, DC 20001.

surface. The sieving action shall be such that the criterion for adequacy of sieving described in 8.4 is met in a reasonable time period.

NOTE 2—Use of a mechanical sieve shaker is recommended when the size of the sample is 20 kg or greater, and may be used for smaller samples, including fine aggregate. Excessive time (more than approximately 10 min) to achieve adequate sieving may result in degradation of the sample. The same mechanical sieve shaker may not be practical for all sizes of samples, since the large sieving area needed for practical sieving of a large nominal size coarse aggregate very likely could result in loss of a portion of the sample if used for a small sample of coarse aggregate or fine aggregate.

6.4 *Oven*—An oven of appropriate size capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

7. Sampling

7.1 Sample the aggregate in accordance with Practice D 75. The weight of the field sample shall be the weight shown in Practice D 75 or four times the weight required in 7.4 and 7.5 (except as modified in 7.6), whichever is greater.

7.2 Thoroughly mix the sample and reduce it to an amount suitable for testing using the applicable procedures described in Practice C 702. The sample for test shall be approximately of the weight desired when dry and shall be the end result of the reduction. Reduction to an exact predetermined weight shall not be permitted.

NOTE 3—Where sieve analysis, including determination of material finer than the 75-μm sieve, is the only testing proposed, the size of the sample may be reduced in the field to avoid shipping excessive quantities of extra material to the laboratory.

7.3 *Fine Aggregate*—The test sample of fine aggregate shall weigh, after drying, approximately the following amount:

Aggregate with at least 95 % passing a 2.36-mm (No. 8) sieve	100 g
Aggregate with at least 85 % passing a 4.75-mm (No. 4) sieve and more than 5 % retained on a 2.36-mm (No. 8) sieve	500 g

7.4 *Coarse Aggregate*—The weight of the test sample of coarse aggregate shall conform with the following:

Nominal Maximum Size, Square Openings, mm (in.)	Minimum Weight of Test Sample, kg (lb)
9.5 (⅜)	1 (2)
12.5 (½)	2 (4)
19.0 (¾)	5 (11)
25.0 (1)	10 (22)
37.5 (1½)	15 (33)
50 (2)	20 (44)
63 (2½)	35 (77)
75 (3)	60 (130)
90 (3½)	100 (220)
100 (4)	150 (330)
112 (4½)	200 (440)
125 (5)	300 (660)
150 (6)	500 (1100)

7.5 *Coarse and Fine Aggregate Mixtures*—The weight of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate in 7.4.

7.6 The size of sample required for aggregates with large nominal maximum size is such as to preclude testing except with large mechanical sieve shakers. However, the intent of this method will be satisfied for samples of aggregate larger than 50 mm nominal maximum size if a smaller weight of sample is used, provided that the criterion for acceptance or rejection of the material is based on the average of results of several samples, such that the sample size used times the number of samples averaged equals the minimum weight of sample shown in 7.4.

7.7 In the event that the amount of material finer than the 75-μm (No. 200) sieve is to be determined by Test Method C 117, proceed as follows:

7.7.1 For aggregates with a nominal maximum size of 12.5 mm (1/2 in.) or less, use the same test sample for testing by Test Method C 117 and this method. First test the sample in accordance with Test Method C 117 through the final drying operation, then dry sieve the sample as stipulated in 8.2 through 8.7 of this method.

7.7.2 For aggregates with a nominal maximum size greater than 12.5 mm (1/2 in.), a single test sample may be used as described in 7.7.1, or separate test samples may be used for Test Method C 117 and this method.

7.7.3 Where the specifications require determination of the total amount of material finer than the 75-μm sieve by washing and dry sieving, use the procedure described in 7.7.1.

8. Procedure

8.1 Dry the sample to constant weight at a temperature of 110 ± 5°C (230 ± 9°F).

NOTE 4—For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate for the sieve analysis test. The results are little affected by the moisture content unless: (*1*) the nominal maximum size is smaller than about 12.5 mm (½ in.); (*2*) the coarse aggregate contains appreciable material finer than 4.75 mm (No. 4); or (*3*) the coarse aggregate is highly absorptive (a lightweight aggregate, for example). Also, samples may be dried at the higher temperatures associated with the use of hot plates without affecting results, provided steam escapes without generating pressures sufficient to fracture the particles, and temperatures are not so great as to cause chemical breakdown of the aggregate.

8.2 Suitable sieve sizes shall be selected to furnish the information required by the specifications covering the material to be tested. The use of additional sieves may be desirable to provide other information, such as fineness modulus, or to regulate the amount of material on a sieve. Nest the sieves in order of decreasing size of opening from top to bottom and place the sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period, established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy or sieving described in 8.4.

8.3 Limit the quantity of material on a given sieve so that all particles have opportunity to reach sieve openings a number of times during the sieving operation. For sieves with openings smaller than 4.75-mm (No. 4), the weight retained on any sieve at the completion of the sieving operation shall not exceed 6 kg/m^2 (4 g/in.^{2}) of sieving surface. For sieves with openings 4.75 mm (No. 4) and larger, the weight in kg/m^2 of sieving surface shall not exceed the product of 2.5 × (sieve opening in mm). In no case shall the weight be so great as to cause permanent deformation of the sieve cloth.

NOTE 5—The 6 kg/m^2 amounts to 194 g for the usual 203-mm (8 in.) diameter sieve. The amount of material retained on a sieve may be regulated by (*1*) the introduction of a sieve with larger openings immediately above the given sieve or (*2*) testing the sample in a number of increments.

8.4 Continue sieving for a sufficient period and in such

manner that, after completion, not more than 1 weight % of the residue on any individual sieve will pass that sieve during 1 min of continuous hand sieving performed as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of the sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75-mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203-mm (8 in.) diameter sieves to verify the sufficiency of sieving.

8.5 In the case of coarse and fine aggregate mixtures, the portion of the sample finer than the 4.75-mm (No. 4) sieve may be distributed among two or more sets of sieves to prevent overloading of individual sieves.

8.5.1 Alternatively, the portion finer than the 4.75-mm (No. 4) sieve may be reduced in size using a mechanical splitter according to Practice C 702. If this procedure is followed, compute the weight of each size increment of the original sample as follows:

$$A = \frac{W_1}{W_2} \times B$$

where:

A = weight of size increment on total sample basis,
W_1 = weight of fraction finer than 4.75-mm (No. 4) sieve in total sample,
W_2 = weight of reduced portion of material finer than 4.75-mm (No. 4) sieve actually sieved, and
B = weight of size increment in reduced portion sieved.

8.6 Unless a mechanical sieve shaker is used, hand sieve particles larger than 75 mm (3 in.) by determining the smallest sieve opening through which each particle will pass. Start the test on the smallest sieve to be used. Rotate the particles, if necessary, in order to determine whether they will pass through a particular opening; however, do not force particles to pass through an opening.

8.7 Determine the weight of each size increment by weighing on a scale or balance conforming to the requirements specified in 5.1 to the nearest 0.1 % of the total original dry sample weight. The total weight of the material after sieving should check closely with original weight of sample placed on the sieves. If the amounts differ by more than 0.3 %, based on the original dry sample weight, the results should not be used for acceptance purposes.

8.8 If the sample has previously been tested by Test Method C 117, add the weight finer than the 75-μm (No. 200) sieve determined by that method to the weight passing the 75-μm (No. 200) sieve by dry sieving of the same sample in this method.

9. Calculation

9.1 Calculate percentages passing, total percentages retained, or percentages in various size fractions to the nearest 0.1 % on the basis of the total weight of the initial dry sample. If the same test sample was first tested by Test Method C 117, include the weight of material finer than the 75-μm (No. 200) size by washing in the sieve analysis calculation; and use the total dry sample weight prior to washing in Test Method C 117 as the basis for calculating all the percentages.

9.2 Calculate the fineness modulus, when required, by adding the total percentages of material in the sample that is coarser than each of the following sieves (cumulative percentages retained), and dividing the sum by 100: 150-μm (No. 100), 300-μm (No. 50), 600-μm (No. 30), 1.18-mm (No. 16), 2.36-mm (No. 8), 4.75-mm (No. 4), 9.5-mm (3/8-in.), 19.0-mm (3/4-in.), 37.5-mm (1½-in.), and larger, increasing in the ratio of 2 to 1.

10. Report

10.1 Depending upon the form of the specifications for use of the material under test, the report shall include the following:

10.1.1 Total percentage of material passing each sieve, or

10.1.2 Total percentage of material retained on each sieve, or

10.1.3 Percentage of material retained between consecutive sieves.

10.2 Report percentages to the nearest whole number, except if the percentage passing the 75-μm (No. 200) sieve is less than 10 %, it shall be reported to the nearest 0.1 %.

10.3 Report the fineness modulus, when required, to the nearest 0.01.

11. Precision

11.1 The estimates of precision of this method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Reference Sample Program, with testing conducted by this method and AASHTO Method T 27. While there are differences in the minimum weight of the test sample required for other nominal maximum sizes of aggregate, no differences entered into the testing to affect the determination of these precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories. The values in the table are given for different ranges of percentage of aggregate passing one sieve and retained on the next finer sieve.

12. Keywords

12.1 aggregate; coarse aggregate; fine aggregate; gradation; grading; sieve analysis; size analysis

TABLE 1 Precision

	% of Size Fraction Between Consecutive Sieves	Coefficient of Variation (1S %), %[B]	Standard Deviation (1S), %[A]	Acceptable Range of Test Results (D2S %)[B] % of Avg.	Acceptable Range of Test Results (D2S),[A] %
Coarse Aggregates:[C]					
Single-Operator	0 to 3	30[D]	...	85[D]	...
Precision	3 to 10		1.4[D]		4.0[D]
	10 to 20		0.95		2.7
	20 to 50		1.38		3.9
Multilaboratory	0 to 3	35[D]	...	99[D]	...
Precision	3 to 10		1.06		3.0
	10 to 20		1.66		4.7
	20 to 30		2.01		5.7
	30 to 40		2.44		6.9
	40 to 50		3.18		9.0
Fine Aggregates:					
Single-Operator	0 to 3		0.14		0.4
Precision	3 to 10		0.43		1.2
	10 to 20		0.60		1.7
	20 to 30		0.64		1.8
	30 to 40		0.71		2.0
	40 to 50		...		...
Multilaboratory	0 to 3		0.21		0.6
Precision	3 to 10		0.57		1.6
	10 to 20		0.95		2.7
	20 to 30		1.24		3.5
	30 to 40		1.41		4.0
	40 to 50		...		...

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.
[B] These numbers represent, respectively, the (1s %) and (d2s %) limits as described in Practice C 670.
[C] The precision estimates are based on coarse aggregates with nominal maximum size of 19.0 mm (¾ in.).
[D] These values are from precision indices first included in Method C 136 – 77. Other indices were developed in 1982 from more recent AASHTO Materials Reference Laboratory sample data, which did not provide sufficient information to revise the values so noted.

Appendix B
Iowa DOT Materials Laboratory Test Method 212
Method of Test for Determining Mortar Strength Ratios of Concrete Sands

IOWA DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION

Office of Materials

METHOD OF TEST FOR DETERMINING MORTAR STRENGTH RATIOS OF CONCRETE SANDS

Scope

This method of tests covers the determination of mortar strength ratios of concrete sand. The apparatus and procedures in the test are identical with those specified in AASHTO T106 (ASTM C109), with the following exceptions:

1. The fine aggregate being tested, less the plus No. 4 material, shall be substituted for the standard sand prescribed.

2. The portland cement used in the test shall be the laboratory blend unless otherwise specified.

3. The quantity of mixing water, measured in milliliters, shall be such to produce a flow of between 100 and 115 as determined in accordance with 8.3 of ASTM C109 and shall be expressed as a percentage by weight of the cement.

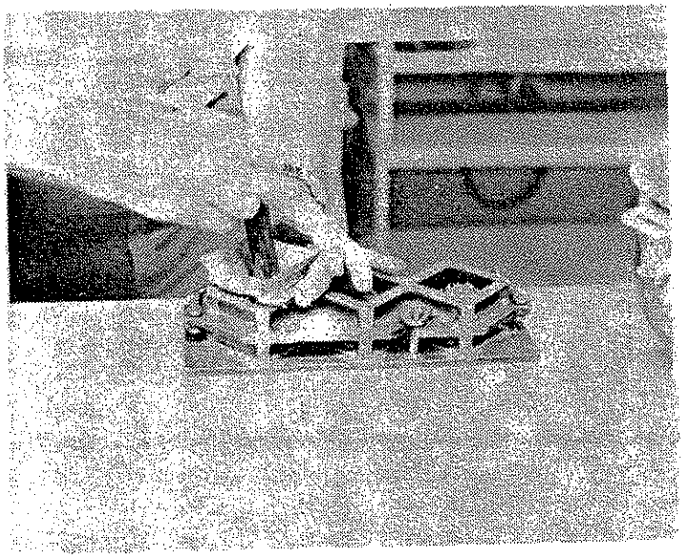


Figure 2. Tamping Cubes

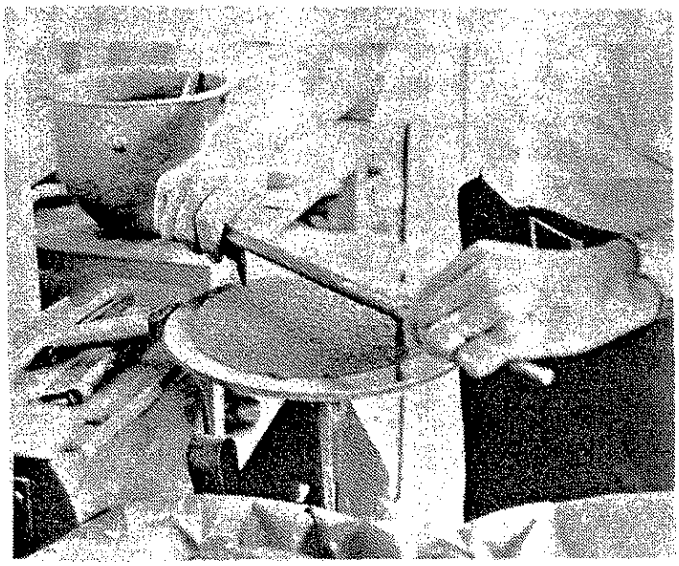


Figure 1. Flow Table

Figure 3. Weighing Material

Appendix C
Standard Test Method for Particle Shape, Texture
and Uncompacted Void Content of Fine Aggregate

Standard Test Method for Particle Shape, Texture, and Uncompacted Void Content of Fine Aggregate

1. SCOPE

1.1 This method covers the determination of the loose uncompacted void content of a fine sample of aggregate. When measured using aggregate of a given grading, it provides a measure of its angularity and texture compared to other fine aggregates tested in the same grading. When void content is measured on an as-received fine aggregate grading, it can be an indicator of the effect of the fine aggregate on the workability of a concrete mixture in which it may be used.

1.2 Three procedures are included for the measurement of void content using graded sand (standard grading or as-received grading) or through the use of several individual size fractions for void content determinations:

1.2.1 Standard Graded Sample (Method A) -- This method uses a standard sand grading that can be obtained from the individual sieve fractions in a typical fine aggregate sieve analysis. See the section on Preparation of Test Samples for the grading.

1.2.2 Individual Size Samples (Method B) -- This method uses each of three fine aggregate size fractions: (1) 2.36 mm (No. 8) to 1.18 mm (No. 16); (2) 1.18 mm (No. 16) to 600-um (No. 30); (3) 600-um (No. 30) to 300-um (No. 50). For this method, each size is tested separately.

1.2.3 As-Received Grading (Method C) -- This method uses that portion of the fine aggregate finer than a 4.75 mm (No. 4) sieve.

2. REFERENCED DOCUMENTS

2.1 ASTM Standards

2.1.1 B 88 Specification for Seamless Copper Water Tube.

2.1.2 C 117 Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing.

2.1.3 C 125 Terminology Relating to Concrete and Concrete Aggregates.

2.1.4 C 128 Test Method for Specific Gravity and Absorption of Fine Aggregate.

2.1.5 C 136 Method for Sieve Analysis of Fine and Coarse Aggregate.

2.1.6 C 702 Practice for Reducing Field Samples of Aggregate to Testing Size.

2.1.7 C 778 Specification for Standard Sand

2.1.8 D 75 Practice for Sampling Aggregates.

2.2 ACI Document

2.2.1 ACI 116R Cement and Concrete Terminology[1]

3. TERMINOLOGY

3.1 Terms used in this standard are defines in Terminology C 125 or ACI 116R.

4. SUMMARY OF TEST METHOD

4.1 A nominal 100 cm^3 cylinder is filled with fine aggregate of prescribed grading by allowing the sample to flow through a funnel from a fixed height into the calibrated cylinder. The cylinder is struck off and the mass determined by weighing. Uncompacted void content is calculated as the difference between the cylinder volume and the absolute volume of the fine aggregate collected in the cylindrical container. It is calculated using the bulk dry specific gravity of the fine aggregate. Two runs are made on each sample and the results are averaged.

4.1.1 For a graded sample (Method A or Method C) the void content so determined is used directly.

---

[1] Copies may be obtained from the American Concrete Institute, Box 19150, Detroit, MI 48219.

4.1.2 For the individual size fractions (Method B), the mean void content percent is calculated using the void content results from tests of each of the three individual size fractions: 2.36 -mm (No. 8) to 1.18-mm (No. 16), 1.18-mm (No. 16) to 600-um (No. 30), and 600-um (No. 30) to 300-um (No. 50).

5. SIGNIFICANCE AND USE

5.1 Methods A and B provide a numerical result in terms of percent void content determined under standardized conditions which correlates with the particle shape and texture of a fine aggregate. An increase in void content by these procedures indicates greater angularity or rougher texture or both. Lower void content results are associated with more rounded, smooth surfaced fine aggregate.

5.2 Method C gives uncompacted void content of the as-received material. This void content will be affected by both grading and particle shape.

5.3 The void content determined on the standard graded sample (Method A) is not directly comparable with the average void content of the three individual size fractions from the same sample tested separately (Method B). A sample consisting of single size particles will have a higher void content than a graded sample. Therefore, use either one method or the other as a measure of shape and texture; and identify which method is applicable with respect to reported data. Method C does not indicate shape and texture directly if the grading changes.

5.3.1 The standard graded sample (Method A) is most useful as a quick test which indicates the particle shape properties of a graded fine aggregate. Typically, the material used to make up the standard graded sample can be obtained from a single sieve analysis of the fine aggregate.

5.3.2 Obtaining and testing individual size fractions (Method B) is more time consuming than using the graded sample.

5.3.3 The sample in the as-received grading (Method C) is useful in selecting the proportions of components used in portland cement concrete mixtures. High voids content indicates the need for more fines in the fine aggregate or use of more cementitious material to produce

mixtures having the same workability characteristics. The most economical mixture will be obtained by use of a fine aggregate that has the lowest uncompacted void content.

5.3.4 Generally, the bulk dry specific gravity of the fine aggregate, graded as received, is used for calculating the void content. Occasionally, if the type of rock in of the size fractions varies markedly it may be necessary to determine the specific gravity of the size fraction used.

5.4 Void content information from Methods A, B, or C will be useful as an indicator of properties such as: the mixing water demand of portland cement concrete; in asphaltic concrete, the effect of the fine aggregate on stability and voids in the mineral aggregate; or the stability of the fine aggregate phase of a base course aggregate.

6. APPARATUS

6.1 Funnel -- The lateral surface of the right frustum of a cone sloped 60 ± 4° from the horizontal with an opening of 0.50 ± 0.025 in. in diameter. The funnel shall be smooth on the inside and at least 1.5 in. (38 mm) high. It shall have a volume of at least 200 cm^3 or shall be provided with a supplemental container to provide the required volume.

Note 1 -- Pycnometer top C9455 sold by Hogentogler and Co., Inc., 9515 Gerwig, Columbia, Maryland 21045, 301-381-2390 appears to be satisfactory, except that the size of the opening has to be enlarged and any burrs or lips that are apparent should be removed by light filing or sanding.

6.2 Funnel stand -- A support capable of holding the funnel firmly in position with its axis colinear with the axis of the measure and funnel opening 4.5 ± 0.1 in. (114 ± 3 mm) above the top of the cylinder. A suitable arrangement is shown in Figure 1.

6.3 Measure -- A right cylinder of approximately 100 cm^3 capacity having an inside diameter of 1.52 ± 0.05 in. (38.6 ± 1.3 mm) and an inside height of approximately 3.37 in. (85.6 mm) made of drawn copper water tube meeting Specification B 88 Type M or equally rigid material. The bottom of the measure shall be at least 0.25 in. (6.3 mm) thick, shall be firmly sealed to the tubing, and shall be provided with means for aligning the

axis of the cylinder with that of the funnel. See Figure 2.

Note 2 -- Type M copper drain, waste and vent pipe should have outside and inside diameters of approximately 1.63 in. (41.4 mm) and 1.52 in. (38.6 mm), respectively.

6.4 Pan -- A metal or plastic pan of sufficient size to contain the funnel stand and to prevent loss of material. The purpose of the pan is to catch and retain sand grains that overflow the measure during filling or strike off.

6.5 Metal spatula about 4 in. (100 mm) long with sharp straight edges. The end shall be cut at a right angle to the edges. The straight edge of the spatula is used to strike off the fine aggregate.

6.6 Scale or balance accurate and readable to ± 0.1g within the range of use, capable of weighing the measure and its contents to ± 0.1 g.

7. SAMPLING

7.1 The sample(s) used for this test shall be obtained using Method D 75 and Practice C 702, from sieve analysis samples used for Method C 136, or from aggregate extracted from an asphaltic concrete specimen. For Methods A and B, the sample is washed over a 150-um (No. 100) or 75-um (No. 200) sieve in accordance with the methods in ASTM C 117 and then dried and sieved into separate size fractions using ASTM C 136 procedures. Maintain the necessary size fractions obtained from one (or more) sieve analysis in a dry condition in separate containers for each size. For Method C, dry a split of the as-received sample.

8. CALIBRATION OF MEASURE

8.1 Apply a light coat of grease to the top edge of the dry, empty measure. Weigh the measure, grease, and a flat, glass plate slightly larger than the diameter of the measure. Fill the measure with water at a temperature of 65 to 75° F (18 to 24° C). Place the glass plate on the measure, being sure that no air bubbles remain. Dry the outer surfaces of the measure and determine the combined mass of measure, glass plate, grease, and water by weighing.

8.2 Calculate the volume of the measure as follows:

$$V = \frac{W}{0.998}$$ where:

V = volume of cylinder, cm^3

W = net mass of water, g

9. PREPARATION OF TEST SAMPLES

9.1 Method A - Standard Graded Sample -- weigh out and combine the following quantities of dry sand from each of the sizes:

Individual Size Fraction	Mass, g
2.36-mm (No. 8) to 1.18-mm (No. 16)	44
1.18-mm (No. 16) to 600-um (No. 30)	57
600-um (No. 30) to 300-um (No. 50)	72
300-um (No. 50) to 150-um (No. 100)	17
	190

The tolerance on each of these amounts is ± 0.2 g. Mix the test sample until it is homogenous.

9.2 Method B - Individual Size Samples -- Prepare a separate 190 g sample of dry fine aggregate for each of the following size fractions:

Individual Size Fraction	Mass, g
2.36-mm (No. 8) to 1.18-mm (No. 16)	190
1.18-mm (No. 16) to 600-um (No. 30)	190
600-um (No. 30) to 300-um (No. 50)	190

The tolerance on each of these amounts is ± 1 g. Do not mix these samples together. Each size is tested separately.

9.3 Method C - As Received Grading -- Pass the dry sample through a 4.75-mm (No. 4) sieve and remove any coarse particles. Obtain an approximate 190 g sample of the material passing the 4.75-mm (No. 4) sieve for test.

10. PROCEDURE

10.1 If the fine aggregate has become moist, dry it to constant weight in accordance with Method C 136 and cool to room temperature.

10.2 Mix the test sample until it is homogenous. Using a finger to block the opening of the funnel, pour the test sample into the funnel. Level the material in the funnel with the spatula. Center the measure under the funnel, remove the finger, and allow the sample to fall freely into the measure.

10.3 After the funnel empties, remove excess heaped sand from the measure by a single pass of the spatula with the blade vertical using the straight part of its edge in light contact with the top of the measure. Until this operation is complete, exercise care to avoid vibration or disturbance that could cause compaction of the fine aggregate in the measure. (Note 3) Brush adhering grains from the outside of the measure and determine the mass of the measure and contents to the nearest 0.1 g. Retain all sand grains.

Note 3 -- After strike-off the measure may be tapped lightly to compact the sample to make it easier to transfer the measure to scale or balance without spilling any of the sample.

10.4 Collect the sample from the retaining pan and measure, recombine, and repeat the procedure again. The results of two runs are averaged. See Calculation section below.

10.5 For each run, record the mass of the container and fine aggregate. Also, record the mass of the empty measure.

11. CALCULATION

11.1 Calculate the uncompacted voids for each determination as follows:

$$U = \frac{V - (F/G)}{V} \times 100$$

V = volume of measure, cm^3.

F = net mass of fine aggregate in measure (Gross mass minus the mass of the empty measure).

G = bulk dry specific gravity of fine aggregate measured

in accordance with Method C 128.

U = uncompacted voids, percent, in the material.

Note 4 -- For most aggregate sources the fine aggregate specific gravity does not vary much from sample to sample or from size to size finer than the 2.36-mm (No. 8) sieve. Therefore, unless the specific gravity of individual sizes is appreciably different, it is intended that the value used in this calculation may be from a routine specific gravity test of an as-received grading of the fine aggregate. If significant variation between different samples is expected, the specific gravity should be determined on material from the same field sample from which the uncompacted void content sample was derived. Normally the as-received grading can be tested for specific gravity, particularly if the 2.36-mm (No. 8) to 150-um (No. 100) size fraction represents more than 50 percent of the as-received grading. However, it may be necessary to test the graded 2.36-um (No. 8) to 150-mm (No. 100) sizes for specific gravity for use with the graded void sample (Method A) or the individual size fractions for use with the individual size method (Method B). A difference in specific gravity of 0.05 will change the calculated void content about one percent.

11.2 For the Standard Graded Sample (Method A) calculate the average uncompacted voids for the two determinations and report the result as U_s.

11.3 For the Individual Size Fractions (Method B) calculate:

11.3.1 First, the average uncompacted voids for the determinations made on each of the three size-fraction samples:

U_1 = Uncompacted Voids, 2.36-mm (No. 8) - 1.18-mm (No. 16), percent

U_2 = Uncompacted Voids, 1.18-mm (No. 16) - 600-um (No. 30), percent

U_3 = Uncompacted Voids, 600-um (No. 30) - 300-um (No. 50), percent

11.3.2 Second, the mean uncompacted voids (U_m) including the results for all three sizes:

$$U_m = (U_1 + U_2 + U_3) / 3$$

11.4 For the As-Received grading (Method C) calculate the average uncompacted voids for the two determinations and report the result as U_R.

12. REPORT

12.1 For the Standard Graded Sample (Method A) report:

12.1.1 The Uncompacted Voids (U_s) in percent to the nearest one-tenth of a percent.

12.1.2 The specific gravity value used in the calculation.

12.2 For the Individual Size Fractions (Method B) report the following percent voids to the nearest one-tenth of a percent:

12.2.1 Uncompacted Voids for size fractions 2.36-mm (No. 8) - 1.18-mm (No. 16) (U_1), 1.18 mm (No. 16) - 600-um (No. 30) (U_2), and 600-um (No. 30) - 300-um (No. 50) (U_3).

12.2.2 Mean Uncompacted Voids (U_m).

12.2.3 Specific gravity value(s) used in the calculations, and whether the specific gravity value(s) were determined on: (a) another sample from the same source (b) as-received gradation from this sample, or (c) individual size fractions from this sample.

12.3 For the As-Received Sample (Method C) report:

12.3.1 The uncompacted voids (U_R) in percent to the nearest one-tenth of a percent.

12.3.2 The specific gravity value used in the calculation.

13. PRECISION AND BIAS

13.1 Precision

13.1.1 Within Laboratory Precision. Analysis of within-laboratory data from sixteen laboratories which made void content tests on independent samples of three similar sources of rounded sands, graded in accordance with the graded standard sand in C 778, resulted in a within-laboratory standard deviation (1S) of

0.13 percent voids for repeat determinations on the same sample.

Differences greater than 0.37 percent voids between duplicate tests on the same sample by the same operator should occur by chance less than 5 percent of the time (D2S limit).

12.1.2 Multi-Laboratory -- Analysis of data from sixteen laboratories which made void content tests on independent samples of three similar sources of rounded sands, graded in accordance with the graded standard sand in C 778, resulted in multi-laboratory standard deviation (1S) of 0.33 percent voids. Since this value includes random variance due to the difference in samples, the standard deviation for multi-laboratory tests on the same sample should be lower. Differences greater than 0.93 percent voids between tests in two different labs should occur by chance less than 5 percent of the time (D2S limit) for these rounded sands.

13.1.3 Additional precision data are needed for tests of sands having different levels of angularity and texture tested in accordance with the procedures included in this Method.

13.2 Bias

Since there is no accepted reference material suitable for determining the bias for the procedures in Test Method C xxxx, bias has not been determined.

14. Keywords: Angularity, Concrete, Fine Aggregate, Particle Shape, Roughness, Sand, Surface Texture, Void Content, Workability (of Concrete)

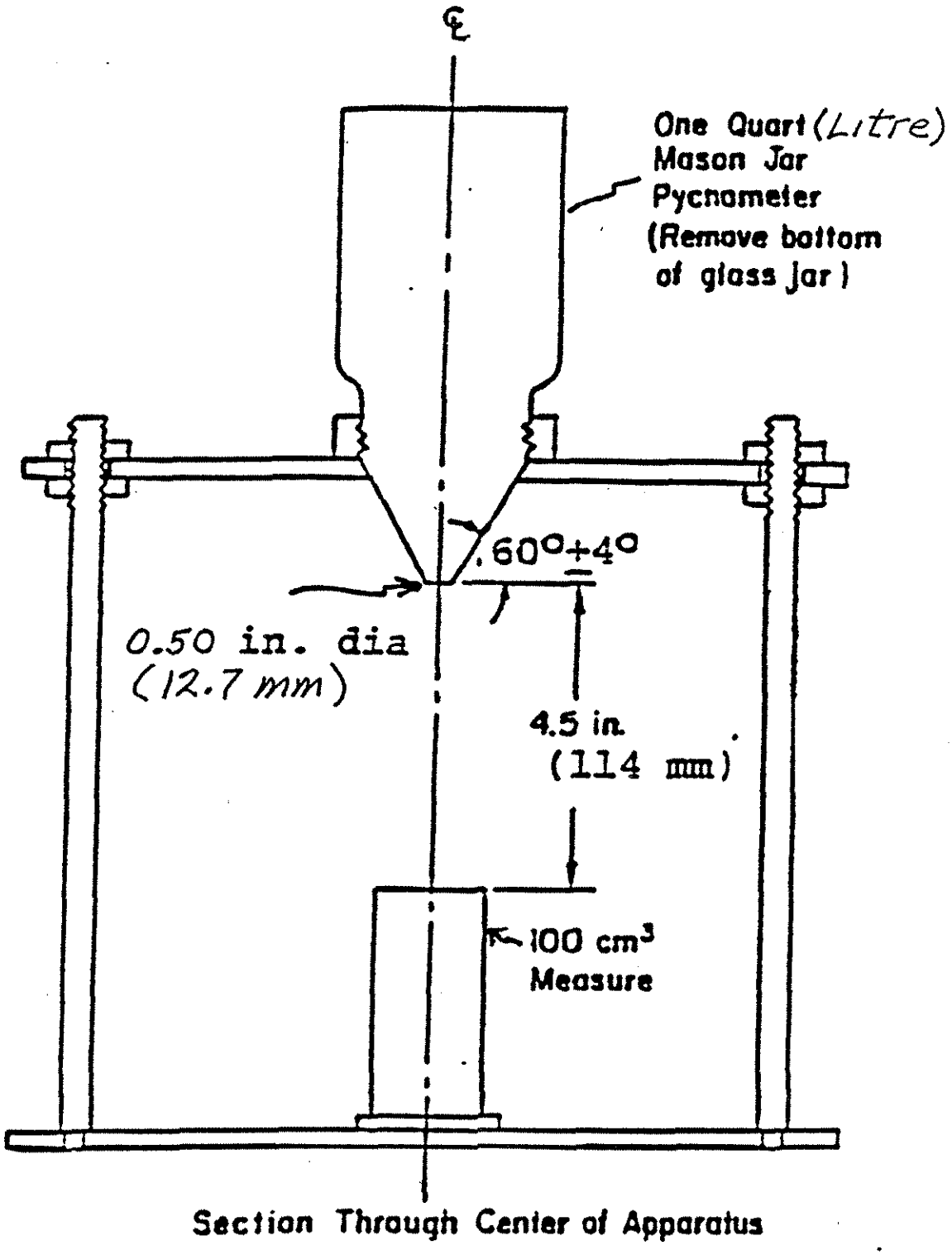


Figure 1-- Funnel Stand Apparatus with Measure in Place

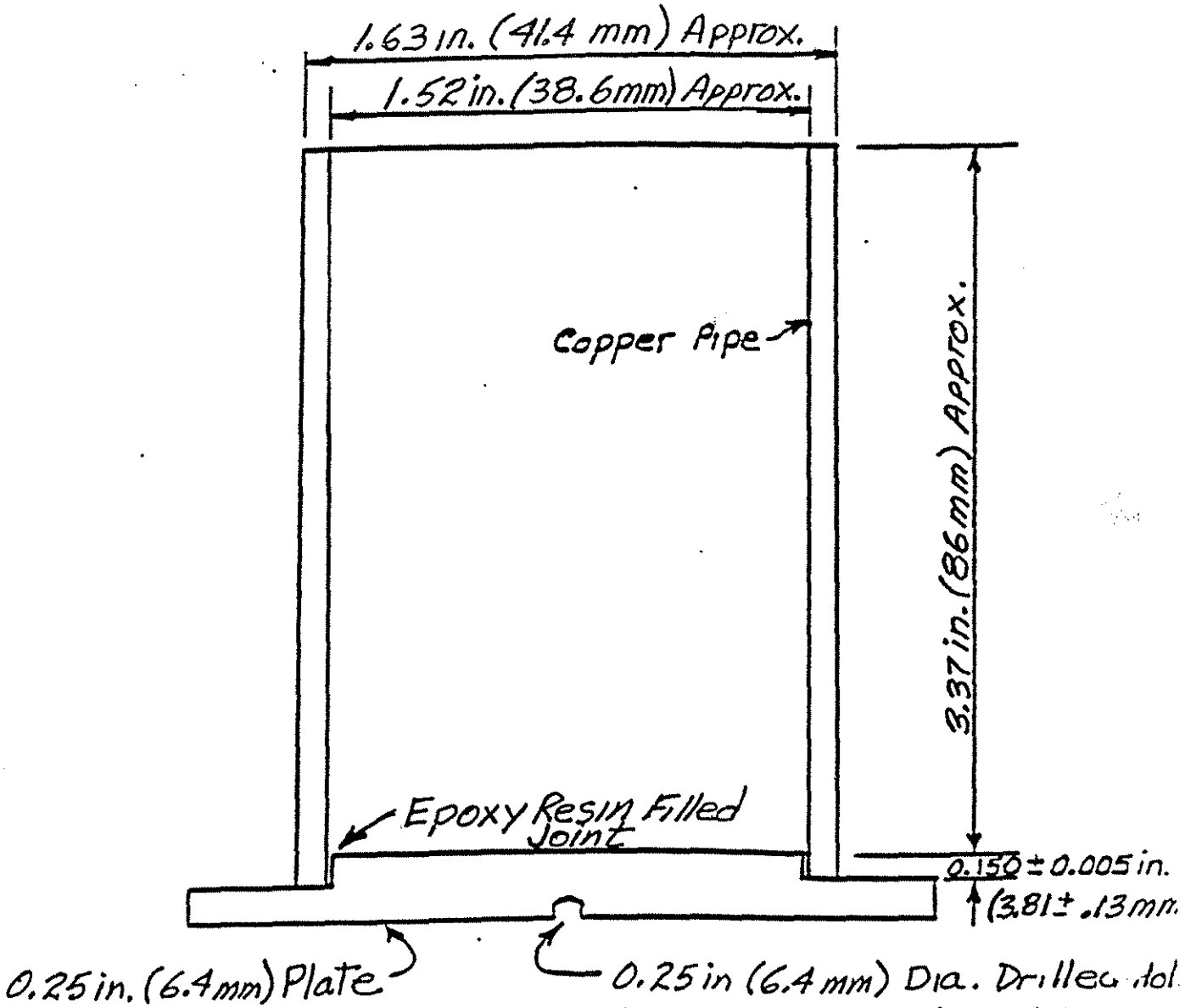


Figure 2 -- Nominal 100 cm^3 Measure

Appendix D
ASTM P214 - Proposed Test Method for Accelerated Detection
of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction

Proposed Test Method for Accelerated Detection of Potentially Deleterious Expansion of Mortar Bars Due to Alkali-Silica Reaction[1]

This proposed Test Method has no status as an ASTM standard and is published on behalf of the sponsoring committee for information only for a maximum of two years. Comments are solicited and should be addressed to the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103. When referencing this document, the word "Proposal" must precede the P designation.

1. Scope

1.1 This proposed test method allows detecting within 16 days the potential for deleterious expansion of mortar bars due to the alkali-silica reaction.

1.2 *This proposed standard may involve hazardous materials, operations and equipment. This proposed standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this proposed standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* A specific precautionary statement is given in Note 5.

1.3 The values stated in inch-pound units are to be regarded as standard. The values in SI units are shown in parentheses, and are for informational purposes only.

2. Referenced Documents

2.1 *ASTM Standards:*

C 33 Specification for Concrete Aggregates[2]

C 109 Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)[3]

C 150 Specification for Portland Cement[2,3]

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar Bar Method)[2]

C 289 Test Method for Potential Reactivity of Aggregates (Chemical Method)[2]

C 295 Practice for Petrographic Examination of Aggregates for Concrete[2]

C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency[3]

C 490 Specification for Apparatus for Use in Measurement of Length Change of Hardened Cement Paste, Mortar, and Concrete[2,3]

C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes[2,3]

C 856 Practice for Petrographic Examination of Hardened Concrete[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

D 1193 Specification for Reagent Water[5]

3. Significance and Use

3.1 This proposed test method provides a means of detecting the potential of an aggregate used in concrete for undergoing alkali-silica reaction and resulting potentially deleterious internal expansion. It is based on the NBRI Accelerated Test Method.[6,7,8] It provides an alternative method to Test Method C 227 and may be especially useful for aggregates that react slowly or produce expansion late in the reaction.

NOTE 1—Because the specimens are exposed to a NaOH solution, the alkali content of the cement is not a significant factor in affecting expansions.

3.2 When expansions greater than 0.10 % are developed within 16 days from casting, it is strongly recommended that supplementary information be developed to confirm that the expansion is actually due to alkali reactivity. Sources of such supplementary information include: (1) petrographic examination of the aggregate (Practice C 295) to determine if known reactive constituents are present; (2) examination of the specimens after tests (Practice C 856) to identify the products of alkali reactivity; and (3) tests of the aggregate for potential reactivity by chemical methods (Test Method C 289).

3.3 When it has been concluded from the results of tests performed using this proposed test method and supplementary information that a given aggregate should be considered potentially deleteriously reactive, additional studies, possibly using alternative methods, may be appropriate to develop information on the potential reactivity of other combinations containing the same cement with other aggregates, or the same cement-aggregate combination with a mineral admixture or ground blast-furnace slag.

4. Apparatus

4.1 The apparatus shall conform to Specification C 490, except as follows:

4.2 *Sieves*—Square hole, woven-wire cloth sieves, shall conform to Specification E 11.

4.3 *Mixer, Paddle, and Mixing Bowl*—Mixer, paddle, and mixing bowl shall conform to the requirements of Practice

---

[1] This proposed test method is under the jurisdiction of ASTM Committee C-9 on Concrete and Aggregates and is the direct responsibility of Sub-committee C09.02.02 on Chemical Reactions of Aggregates in Concrete.

Published as information only in July 1990.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] *Annual Book of ASTM Standards*, Vol 11.01.

[6] Oberholster, R. E., and Davies, G., "An Accelerated Method for Testing the Potential Alkali Reactivity of Siliceous Aggregates," *Cement and Concrete Research*, Vol 16, 1986, pp. 181–189.

[7] Davies, G., and Oberholster, R. E., "Use of the NBRI Accelerated Test to Evaluate the Effectiveness of Mineral Admixtures in Preventing the Alkali-Silica Reaction," *Cement and Concrete Research*, Vol 17, 1987, pp. 97–107.

[8] Davies, G., and Oberholster, R. E., "An Interlaboratory Test Programme on the NBRI Accelerated Test to Determine the Alkali-Reactivity of Aggregates," National Building Research Institute, CSIRO, Special Report BOU 92-1987, Pretoria, RSA, 1987, 16 pp.

C 305, except that the clearance between the lower end of the paddle and the bottom of the bowl shall be 0.20 ± 0.01 in. (5.1 ± 0.3 mm).

4.4 *Tamper and Trowel*—The tamper and trowel shall conform to Test Method C 109.

4.5 *Containers*—The containers must be of such a nature that the bars can be totally immersed in either the water or 1N NaOH solution. The containers must be made of material that can withstand prolonged exposure to 176°F (80°C) and must be inert to a 1N NaOH solution. The containers must be so constructed that when used for storing specimens, the loss of moisture is prevented by tight-fitting covers, by sealing, or both. The bars in the solution must be placed and supported so that the solution has access to the whole of the bar; therefore, it should be ensured that the specimens do not touch the sides of the container or each other. The specimens, if stood upright in the solution, shall not be supported by the metal gage stud.

NOTE 2—The NaOH solution will corrode glass or metal containers.

NOTE 3—A covered container that has been found to be acceptable for this purpose is sold by Rubbermaid as a microwave-proof food storage container.

4.6 *Oven*—A convection oven with temperature control maintaining 176 ± 3°F (80 ± 1.7°C).

5. Reagents

5.1 *Sodium Hydroxide (NaOH)*—USP or technical grade may be used, provided the Na^+ and OH^- concentrations are shown by chemical analysis to lie between 0.99N and 1.01N.

5.2 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Type IV of Specification D 1193.

5.3 *Sodium Hydroxide Solution*—Each litre of solution shall contain 40.0 g of NaOH dissolved in 900 mL of water, and shall be diluted with additional distilled or deionized water to obtain 1.0 L of solution. The volume proportion of sodium hydroxide solution to mortar bars in a storage container shall be 4 ± 0.5 volumes of solution to 1 volume of mortar bars.

NOTE 4—The volume of a mortar bar may be taken as 11.25 in.^{3} (184 mL).[8]

NOTE 5: **Precaution**—Before using NaOH, review: (1) the safety precautions for using NaOH; (2) first aid for burns; and (3) the emergency response to spills, as described in the manufacturer's Material Safety Data Sheet or other reliable safety literature. NaOH can cause very severe burns and injury to unprotected skin and eyes. Suitable personal protective equipment should always be used. These should include full-face shields, rubber aprons, and gloves impervious to NaOH. Gloves should be checked periodically for pin holes.

6. Conditioning

6.1 The temperature of the molding room and dry materials shall be maintained at not less than 68°F (20°C) and not more than 81.5°F (27.5°C). The temperature of the mixing water, and of the moist closet or moist room, shall not vary from 73.4°F (23°C) by more than 3°F (1.7°C).

6.2 The relative humidity of the molding room shall be not less than 50 %. The moist closet or room shall conform to Specification C 511.

6.3 The storage oven in which the specimens are stored in the containers shall be maintained at a temperature that shall not vary from 176°F (80°C) by more than 3°F (1.7°C).

7. Sampling and Preparation of Test Specimens

7.1 *Selection of Aggregate*—Materials proposed for use as fine aggregate in concrete shall be processed as described in 7.2 with a minimum of crushing. Materials proposed for use as coarse aggregate in concrete shall be processed by crushing to produce as nearly as practical a graded product from which a sample can be obtained. The sample shall have the grading as prescribed in 7.2 and be representative of the composition of the coarse aggregate as proposed for use.

7.1.1 When a given quarried material is proposed for use both as coarse and as fine aggregate, it will be tested only by selection of an appropriate sample crushed to the fine aggregate sizes, unless there is reason to expect that the coarser size fractions have a different composition than the finer sizes and that these differences might significantly affect expansion due to reaction with the alkalies in cement. In this case the coarser size fractions should be tested in a manner similar to that employed in testing the fine aggregate sizes.

7.1.2 Coarse aggregate crushed to sand size may give increased expansion, owing to the increased surface exposed upon crushing. Therefore, if coarse aggregate tested by this test method produces an excessive amount of expansion, the material shall not be classed as objectionably reactive with alkali unless tests of concrete specimens confirm the findings of the tests of the mortar.

7.2 *Preparation of Aggregate*—All aggregates to which this test method is applied shall be graded in accordance with the requirements prescribed in Table 1. Aggregates in which sufficient quantities of the sizes specified in Table 1 do not exist shall be crushed until the required material has been produced. In the case of aggregates containing insufficient amounts of one or more of the larger sizes listed in Table 1, and if no larger material is available for crushing, the first size in which sufficient material is available shall contain the cumulative percentage of material down to that size as determined from the grading specified in Table 1. When such procedures are required, special note shall be made thereof in the test report. After the aggregate has been separated into the various sieve sizes, each size shall be washed with a water spray over the sieve to remove adhering dust and fine particles from the aggregate. The portions retained on the various sieves shall then be dried and, unless used immediately, each such portion shall be stored individually in a clean container provided with a tight-fitting cover.

7.3 *Selection and Preparation of Cement:*

7.3.1 *Reference Cement*—The portland cement used shall meet the requirements of Specification C 150 (see Note 1).

7.3.2 *Preparation of Cement*—Cement for use in this test shall be passed through a 850-μm (No. 20) sieve to remove lumps before use.

7.4 *Preparation of Test Specimens:*

7.4.1 *Number of Specimens*—Make at least three test

TABLE 1 Grading Requirements

Sieve Size		Mass, %
Passing	Retained on	
4.75 mm (No. 4)	2.36 mm (No. 8)	10
2.36 mm (No. 8)	1.18 mm (No. 16)	25
1.18 mm (No. 16)	600 μm (No. 30)	25
600 μm (No. 30)	300 μm (No. 50)	25
300 μm (No. 50)	150 μm (No. 100)	15

specimens for each cement-aggregate combination.

7.4.2 *Preparation of Molds*—Prepare the specimen molds in accordance with the requirements of Specification C 490 except, the interior surfaces of the mold shall be covered with a release agent. A release agent will be acceptable if it serves as a parting agent without affecting the setting of the cement and without leaving any residue that will inhibit the penetration of water into the specimen.

NOTE 6—TFE-fluorocarbon tape complies with the requirements for a mold release agent.

7.4.3 *Proportioning of Mortar*—Proportion the dry materials for the test mortar using 1 part of cement to 2.25 parts of graded aggregate by mass. The quantities of dry materials to be mixed at one time in the batch of mortar for making three specimens shall be 440 g of cement and 990 g of aggregate made up by re-combining the portions retained on the various sieves (see 7.2) in the grading prescribed in Table 1. For natural fine aggregates, use a water to cement ratio equal to 0.44 by mass. For coarse aggregates or manufactured sands, use a water to cement ratio equal to 0.50 by mass.

NOTE 7—Ruggedness tests indicated that mortar bar expansions were less variable at a fixed water to cement ratio than when gaged to a constant flow.[8] The water to cement ratios selected should give acceptable workability in most cases.[9]

7.4.4 *Mixing of Mortar*—Mix the mortar in accordance with the requirements of Practice C 305.

7.4.5 *Molding of Test Specimens*—Mold test specimens with a total elapsed time of not more than 2 min and 15 s after completion of the original mixing of the mortar batch. Fill the molds with two approximately equal layers, each layer being compacted with the tamper. Work the mortar into the corners, around the gage studs, and along the surfaces of the mold with the tamper until a homogeneous specimen is obtained. After the top layer has been compacted, cut off the mortar flush with the top of the mold and smooth the surface with a few strokes of the trowel.

8. Procedure

8.1 *Initial Storage and Measurement*—Place each mold in the moist cabinet or room immediately after molds have been filled. The specimens shall remain in the molds for 24 ± 2 h. Remove the specimens from the molds and, while they are being protected from loss of moisture, properly identify and measure for initial length. The initial and all subsequent measurements shall be made and recorded to the nearest 0.0001 in. (0.002 mm). Place the specimens of each aggregate sample in a storage container with sufficient tap water to totally immerse them. Seal and place the containers in an oven or room at 176 ± 3°F (80 ± 1.7°C) for a period of 24 h.

8.2 *Zero Measurements*—Remove the containers from the oven one at a time. Remove other containers only after the bars in the first container have been measured and returned to the oven. Remove the bars one at a time from the water and dry their surface with a towel paying particular attention to the two metal gage measuring studs. Take the zero measurement of each prism immediately after drying, and read as soon as the bar is in position. Complete the process of drying and measuring within 15 ± 5 s of removing the specimen from the water. After measurement, leave the specimen on a towel until the remainder of the bars have been measured. Place all specimens in separate containers with sufficient 1N NaOH, at 176 ± 3°F (80 ± 1.7°C) for the samples to be totally immersed. Seal the containers and return them to the oven.

NOTE 8—The comparator bar should be measured prior to each set of specimens since the heat from the mortar bars may cause the length of the comparator to change.

8.3 *Subsequent Storage and Measurement*—Undertake subsequent measurement of the specimens periodically, with at least three intermediate readings, for 14 days after the zero reading, at approximately the same time each day. The measuring procedure is identical to that described in 8.2 except that the specimens are returned to their own container after measurement.

9. Calculation

9.1 Calculate the difference between the zero length of the specimen and the length at each period of measurement to the nearest 0.001 % of the effective gage length and record as the expansion of the specimen for that period. Report the average expansion of the three specimens of a given cement-aggregate combination to the nearest 0.01 % as the expansion for the combination for a given period.

9.2 When the mean expansion of the test specimens exceeds 0.20 % at 16 days from casting (14 days from zero reading), it is indicative of potentially deleterious expansion. This value has been determined from tests of aggregates with known field performance in concrete.[10]

9.3 When the mean expansion of the test specimens is less than 0.10 % at 16 days after casting, it is indicative of innocuous behaviour.[10]

9.4 Where the mean expansion of the test specimens is above 0.10 % and less than 0.20 % at 16 days from casting, the results are not as yet conclusive.[10] It is strongly recommended that supplementary information be developed as outlined in 3.2.

10. Report

10.1 The report shall include the following:

10.1.1 Type and source of aggregate,

10.1.2 Type and source of portland cement,

10.1.3 Alkali content of cement as percent potassium oxide (K_2O), sodium oxide (Na_2O), and calculated sodium oxide (Na_2O) equivalent,

10.1.4 Average length change in percent at each reading of the specimens,

10.1.5 Any relevant information concerning the preparation of aggregates, including the grading of the aggregate when it differs from that given in 7.2,

10.1.6 Any significant features revealed by examination of

[9] Rogers, C., *Ontario Ministry of Transportation and Communications*, Personal Communication, Tabulation of mean w/c for acceptable flow of mortar bars with fine and crushed-coarse aggregates, Oct. 25. 1988.

[10] Hooton, R. D. and Rogers, C. A., "Evaluation of Rapid Test Methods for Detecting Alkali-Reactive Aggregates," *Proceedings of the Eighth International Conference on Alkali-Aggregate Reaction*, Kyoto, 1989, pp. 439–444.

the specimens during and after test,

10.1.7 Amount of mixing water expressed as mass percent to cement,

10.1.8 Type, source, proportions and chemical analyses, including Na_2O and K_2O, of any pozzolans employed in the tests, and,

10.1.9 A graph of the length change data from the time of the zero reading to the end of the 16 day period.

11. Precision and Bias

11.1 *Precision*—The precision of this test method has not been determined.

11.2 *Bias*—Since there is no accepted reference material for determining the bias of this test method, no statement on bias is being made.

Appendix E
ASTM C1293 - Standard Test Method for Concrete Aggregates
by Determination of Length Change of Concrete Due to Alkali-Silica Reaction

Designation: C 1293 – 95

Standard Test Method for Concrete Aggregates by Determination of Length Change of Concrete Due to Alkali-Silica Reaction[1]

This standard is issued under the fixed designation C 1293 ; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination, by measurement of length change of concrete prisms, of the susceptibility of a sample of an aggregate for participation in expansive alkali-silica reaction involving hydroxide ions associated with alkalies (sodium and potassium).

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound values in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

C 1260 Test Method for Potential Alkali Reactivity of Aggregates (Mortar Bar Method)[2] (formerly Proposal P 214)

C 33 Specification for Concrete Aggregates[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates[2]

C 138 Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete[2]

C 143 Test Method for Slump of Hydraulic Cement Concrete[2]

C 150 Specification for Portland Cement[3]

C 157 Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete[2]

C 192 Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 227 Test Method for Potential Alkali Reaction of Cement-Aggregate Combinations (Mortar-Bar Method)[2]

C 289 Test Method for Potential Reactivity of Aggregates (Chemical Method)[2]

C 294 Descriptive Nomenclature of Constituents of Natural Mineral Aggregates[2]

C 295 Guide for Petrographic Examination of Aggregates for Concrete[2]

C 490 Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete[3]

C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes[3]

C 702 Practice for Reducing Field Samples of Aggregate to Testing Size[2]

C 856 Practice for Petrographic Examination of Hardened Concrete[2]

D 75 Practice for Sampling Aggregates[3]

D 1193 Specification for Reagent Water[4]

2.2 *CSA Standards:*[5]

CSA A23.1-M90 Concrete Materials and Methods of Concrete Construction, Appendix B

CSA A23.2-14A-M90 Potential Expansivity of Aggregates (Procedure for Length Change due to Alkali-Aggregate Reaction in Concrete Prisms)[6]

3. Terminology

3.1 Terminology used in this standard is as given in Terminology C 125 or Descriptive Nomenclature C 294.

4. Significance and Use

4.1 Alkali-silica reaction is a chemical interaction between some siliceous constituents of concrete aggregates or particles of such constituents in fine aggregates and hydroxyl ions (1).[6] The concentration of hydroxyl ion within the concrete is predominantly controlled by the concentration of sodium and potassium (2).

4.2 This test method is intended to evaluate the potential of an aggregate to expand deleteriously due to any form of alkali-silica reactivity (3,4).

4.3 When selecting a sample or deciding on the number of samples for test, it is important to recognize the variability in lithography of material from a given source, whether a deposit of sand, gravel, or a rock formation of any origin. For specific advice, see Guide C 295.

4.4 This test method is intended for evaluating the behavior of aggregates in an alkaline environment. This test method assesses the potential for deleterious expansion of concrete caused by alkali-silica reaction, of either coarse or fine aggregates, from tests performed under prescribed laboratory curing conditions that will probably differ from field conditions. Thus, actual field performance will not be duplicated due to differences in wetting and drying, temperature, other factors, or combinations of these (5).

---

[1] This test method is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.26 on Chemical Reactions.

Current edition approved May 15, 1995. Published July 1995.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.01.

[4] *Annual Book of ASTM Standards*, Vol 11.01.

[5] Canadian Standards Association Standards for Concrete Construction, 173 Rexdale Blvd., Rexdale, Ontario Canada, MaW1R3.

[6] The boldface numbers in parentheses refer to the list of references at the end of this test method.

4.5 Results of tests conducted as described herein should form a part of the basis for a decision as to whether precautions should be taken against excessive expansion due to alkali-silica reaction. This decision should be made before a particular aggregate is used in concrete construction. Criteria to determine the potential deleteriousness of expansions measured in this test are given in Appendix X1.

4.6 The basic intent of this test method is to develop information on a particular aggregate at a specific alkali level of 5.25 kg/m^3 (8.85 lb/yd^3). It has been found that this high alkali level is required to identify certain deleteriously reactive aggregates (3).

4.7 When the expansions in this test method are greater than the limit shown in X1.2, the aggregate is potentially alkali-reactive. Supplemental information should be developed to confirm that the expansion is actually due to alkali-silica reaction. Petrographic examination of the concrete prisms should be conducted after the test using Practice C 856 to confirm that known reactive constituents are present and to identify the products of alkali-silica reactivity. Confirmation of alkali-silica reaction is also derived from the results of the test methods this procedure supplements (see Appendix X1).

4.8 If the supplemental tests show that a given aggregate is potentially deleteriously reactive, additional studies may be appropriate to evaluate preventive measures in order to allow safe use of the aggregate. Preventive measures are mentioned in Specification C 33.

5. Apparatus

5.1 The molds, the associated items for molding test specimens, and the length comparator for measuring length change conform to the applicable requirements of Test Method C 157 and Practice C 490, and shall have square cross sections of 75.0 ± 0.7 mm (3.00 ± 0.03 in.).

5.2 The storage container options required to maintain the prisms at a high relative humidity are described in 5.2.1.

5.2.1 *Recommended Container*—The recommended containers are 22-litre (5-gal) polyethylene pails with airtight lids and approximate dimensions of 250- to 270-mm (9.8- to 10.6-in.) diameter at bottom, 290 to 310 mm (11.4 to 12.2 in.) at top, by 450 to 480 mm (17.7 to 18.9 in.) high.[7] Prevent significant loss of enclosed moisture due to evaporation with airtight lid seal. Place a perforated rack in the bottom of the storage container so that the prisms are 30 to 40 mm above the bottom. Fill the container with water to a depth of 20 ± 5 mm above the bottom. A significant moisture loss is defined as a loss greater than 3 % of the original amount of water placed at the bottom of the pail. Place a wick of absorbent material consisting of polypropylene fibers around the inside wall of the container from the top so that the bottom of the wick extends into the reagent water.

5.2.2 *Alternative Containers*—Alternative storage containers may be used. Confirm the efficiency of the alternative storage container with an alkali-reactive aggregate of known expansion characteristics.[8] The expansion efficiency is confirmed when expansions at one year obtained using the alternative container are within 10 % of those obtained using the recommended container. Alternative storage containers must contain the required depth of reagent water. When reporting results, note the use of an alternative container, if one is utilized, together with documentation proving compliance with the above.

5.3 The storage environment necessary to maintain the 38.0°C (100.4°F) reaction accelerating storage temperature consistently and homogeneously is described in 5.3.1.

5.3.1 *Recommended Environment*—The recommended storage environment is a sealed space insulated so as to minimize heat loss. Provide a fan for air circulation so the maximum variation in temperature measured within 250 mm (9.8 in.) of the top and bottom of the space does not exceed 2.0°C (3.6°F). Provide an insulated entry door with adequate seals so as to minimize heat loss. Racks for storing containers within the space are not to be closer than 30 mm (1.2 in.) to the sides of the enclosure and are to be perforated so as to provide air flow. Provide an automatically controlled heat source to maintain the temperature at 38.0 ± 2.0°C (100.4 ± 3.6°F) (see Note 1). Record the ambient temperature and its variation within the space to ensure compliance.

NOTE 1—It has been found to be good practice to monitor the efficiency of the storage environment by placing thermocouples inside dummy concrete specimens inside a dummy container within the storage area. The storage room described in Test Method C 227 generally will be satisfactory.

5.3.2 *Alternative Storage Environment*—Use of an alternative storage environment is permitted. Confirm the efficiency of the alternative storage container with an alkali-reactive aggregate of known expansion characteristics.[8] The expansion efficiency is confirmed when expansions at one year obtained using the alternative storage environment are within 10 % of those obtained using the recommended environment. When reporting the results, note the use of an alternative storage environment, if one is utilized, together with documentation proving compliance with the above.

6. Reagents

6.1 *Sodium Hydroxide (NaOH)*—USP or technical grade may be used.

NOTE 2: **Precaution**—Before using NaOH, review: (*1*) the safety precautions for using NaOH; (*2*) first aid for burns; and (*3*) the emergency response to spills as described in the manufacturers Material Safety Data Sheet or other reliable safety literature. NaOH can cause severe burns and injury to unprotected skin and eyes. Always use suitable personal protective equipment including: full-face shields, rubber aprons, and gloves impervious to NaOH (Check periodically for pinholes.).

6.2 *Water:*

6.2.1 Unless otherwise indicated, references to water are understood to mean potable tap water.

6.2.2 The references to reagent grade water are under-

[7] Polyethylene pails used in the food industry have been found to be suitable. Twenty two-litre pails (Model Nos.: pail, 5251; lid, 63493), are available from IPL Products Ltd., 348 Park Street, Suite 201, East Building, North Reading, Mass. 01864.

[8] Non-reactive aggregates and alkali-silica reactive aggregates of known expansion characteristics (6) are available from The Petrographer, Engineering Materials Office, Ministry of Transportation, 1201 Wilson Ave., Downsview, Ontario, Canada, M3M1J8.

stood to mean reagent water as defined by Type III or IV in Specification D 1193.

7. Materials

7.1 *Cement*—Use a cement meeting the requirements for a Type I Portland cement as specified in Specification C 150. The cement must have a total alkali content of 0.9 ± 0.1 % Na_2O equivalent (Na_2Oeq is calculated as percent Na_2O + 0.658 × percent K_2O). Determine the total alkali content of the cement either by analysis or by obtaining a mill run certificate from the cement manufacturer. Add NaOH to the concrete mixing water so as to increase the alkali content of the mixture, expressed as Na_2Oeq, to 1.25 % by mass of cement (see Note 3).

NOTE 3—The value of 1.25 % Na_2O equivalent by mass of cement has been chosen to accelerate the process of expansion rather than to reproduce field conditions.

7.2 *Aggregates:*

7.2.1 To evaluate the reactivity of a coarse aggregate, use a nonreactive fine aggregate. A nonreactive fine aggregate is defined as an aggregate that develops an expansion in the accelerated mortar bar, (see Test Method C 1260) of less than 0.10 % at 14 days (see X1.5 for interpretation of expansion data). Use a fine aggregate meeting all the requirements for concrete aggregates (see Specification C 33) with a fineness modulus of 2.7 ± 0.2.

7.2.2 To evaluate the reactivity of a fine aggregate, use a nonreactive coarse aggregate. Prepare the nonreactive coarse aggregate according to 7.2.3.[8] A nonreactive coarse aggregate is defined as an aggregate that develops an expansion in the accelerated mortar bar (see Test Method C 1260) of less than 0.10 % at 14 days (see X1.5 for interpretation of expansion data). Use a coarse aggregate meeting all the requirements for concrete aggregates, (see Specification C 33). Test the fine aggregate using the grading as delivered to the laboratory.

7.2.3 Sieve all coarse aggregates to which this test method is applied and grade in accordance with the requirements in Table 1. Coarse aggregate fractions larger than 19.0-mm (¾-in.) sieve are not to be tested as such. When petrographic examination using Guide C 295 reveals that the material making up the size fraction larger than the 19.0-mm (¾-in.) sieve is of such a composition and lithology that no difference should be expected compared with the smaller size material, then no further attention need be paid to the larger sizes. If petrographic examination suggests the larger size material to be more reactive, the material should be studied for its effect in concrete according to one or the other alternative procedures described herein:

7.2.3.1 *Proportional Testing*—Crush material larger than the 19.0-mm (¾-in.) sieve to pass the 19.0-mm (¾-in.) sieve. Grade the material passing the 19.0-mm (¾-in.) sieve as per the Table 1 grading, and proportionally add back to the original minus 19.0-mm (¾-in.) grading so as to include the oversized material in a mass proportion equal to its original grading percentage.

7.2.3.2 *Separated Size Testing*—Crush material larger than the 19.0-mm (¾-in.) sieve to pass the 19.0-mm (¾-in.) sieve, grade that material as per Table 1 and test in concrete as a separate aggregate.

7.3 *Concrete Mixture Proportions*—Proportion the concrete mixture to the following requirements:

TABLE 1 Grading Requirement

Sieve Size		Mass (%)
Passing	Retained	
19.0-mm (¾-in.)	12.5-mm (½-in.)	33
12.5-mm (½-in.)	9.5-mm (⅜-in.)	33
9.5-mm (⅜-in.)	4.75-mm (No. 4)	33

7.3.1 *Cement Content*—420 ± 10 kg/m³ (708 ± 17 lb/yd³).

7.3.2 *Volume of Coarse Aggregate Per Unit of Volume of Concrete*—Use a coarse aggregate oven-dry-rodded unit volume of 0.70 ± 0.2 % for all classes of aggregates (for example, lightweight, normal, and heavy weight).

7.3.3 *Water to Cement Ratio*—Maintain water-to-cement ratio in the range of 0.42 to 0.45 by mass. Adjust the water-to-cement ratio within this range to give sufficient workability to permit satisfactory compaction of the concrete in the molds. Report the water-to-cement ratio used.

7.3.4 *Admixture (NaOH)*—Dissolve in the mixing water and add as required to bring the alkali content of the concrete mixture, expressed as Na_2Oeq, up to 1.25 % by mass of cement (see Note 4). Use no other admixture in the concrete.

NOTE 4—A sample calculation for determining the amount of NaOH to be added to the mixing water to increase the alkali content of the cement from 0.90 % to 1.25 %:

Cement content of 1 m³ concrete = 420 kg
Amount of alkali in the concrete = 420 kg × 0.90 %
= 3.78 kg
Specified amount of alkali in concrete = 420 kg × 1.25 %
= 5.25 kg
Amount of alkali to be added to concrete = 5.25 kg − 3.78 kg
= 1.47 kg

The difference (1.47 kg) is the amount of alkali, expressed as Na_2O equivalent, to be added to the mix water. Factor to convert Na_2O to NaOH:
since

$$(Na_2O + H_2O \rightarrow 2\ NaOH)$$

Compound	Molecular Weight
Na_2O	61.98
NaOH	39.997

Conversion factor:

$$2 \times 39.997/61.98 = 1.291;$$

Amount of NaOH required:

$$1.47 \times 1.291 = 1.898\ kg/m^3$$

8. Sampling

8.1 Obtain the aggregate sample in accordance with Practice D 75 and reduce it to test portion size in accordance with Practice C 702.

9. Specimen Preparation

9.1 *Mixing Concrete:*

9.1.1 *General*—Mix concrete in accordance with the standard practice for making and curing concrete test specimens in the laboratory as described in Practice C 192.

9.1.2 *Slump*—Measure the slump of each batch of concrete immediately after mixing in accordance with Test Method C 143.

9.1.3 *Yield, and Air Content*—Determine the yield, and air content of each batch of concrete in accordance with Test Method C 138. Concrete used for slump, yield, and air content tests may be returned to the mixing pan and remixed into the batch.

9.2 Prepare three specimens of the type required for concrete in Test Method C 157 from one batch of concrete (see Note 5).

NOTE 5—It has been found useful to cast an additional (4th) prism that can be removed from the test and sectioned for petrographic examination at any time.

9.3 *Initial Conditioning*—Cure, store, and remove molds in accordance with Test Method C 157.

10. Procedure

10.1 *Initial Comparator Reading*—Follow the procedure of Test Method C 157, except do not place in saturated lime water. Make initial length reading at the time of removal from the mold at an age of 23.5 ± 0.5 h. Thereafter, keep the specimens at 38.0 ± 2°C (100.4 ± 3.6°F) in storage containers in accordance with 5.2.

10.2 *Subsequent Comparator Reading*—Stand the specimen on end. Specimens shall not be in contact with water in the reservoir within the storage container. Seal the container and place container in a 38.0 ± 2°C (100.4 ± 3.6°F) storage environment. At no time should the storage container be in contact with the walls or floor of the 38.0 ± 2°C (100.4 ± 3.6°F) storage environment and there shall be an adequate flow of air around the container.

10.2.1 When the specimens are 7 days old, take a comparator reading after removal of the container and contents from the storage environment according to 10.2.2. Subsequent readings are required at the ages of 28 and 56 days, as well as 3, 6, 9, and 12 months. Additional readings, if required, are suggested at 6-month intervals.

10.2.2 Remove the containers holding the prisms from the 38.0°C (100.4°F) temperature environment and place in a moist cabinet or moist room that is in compliance with Specification C 511 for a period 16 ± 4 h before reading.

10.3 Fabricate all specimens placed in a given storage container at the same time so that all specimens in that container are due for comparator reading at the same time.

10.4 Identify the specimens so as to place the specimens in the comparator with the same end uppermost. After the comparator reading of the prism, replace the specimen in the storage container but invert the uppermost end as compared with the previous storage period. In this way the prisms are not stored through two consecutive storage periods with the same ends uppermost.

11. Calculation

11.1 Calculate the change in length between the initial comparator reading of the specimen and the comparator reading at each time interval to the nearest 0.001 % of the effective gage length and record as the length change of the prism for that period. Calculate the average length change in percentage for the group of prisms at the age.

11.2 Data from at least three bars must be available at any age to constitute a valid test at that age.

12. Report

12.1 Report the following information:

12.1.1 Type and source of coarse and fine aggregates,

12.1.2 Type and source of Portland cement,

12.1.3 The alkali content of the cement as percent potassium oxide (K_2O), sodium oxide (Na_2O), and calculated percent sodium oxide (Na_2O) equivalent,

12.1.4 Concrete mixture proportions based on SSD aggregates, and corrected for yield,

12.1.5 The amount of sodium hydroxide (NaOH) added to the mixing water, expressed as percent sodium oxide (Na_2O) equivalent by mass of the cement,

12.1.6 The water-to-cement ratio (w/c) based on saturated, surface dry (SSD) aggregates,

12.1.7 The slump, with mass yield and air content of the concrete batched,

12.1.8 The average length change in percent at each reading of the prisms along with the individual length change in percentage for each prism,

12.1.9 Any significant features revealed by examination of the concrete prisms either during the test or at the end of the test (for example, cracks, gel formation, or peripheral reaction rims on aggregate particles), and

12.1.10 Type of storage container and 38.0°C storage environment used to store the concrete prisms if they differ from those specified in 5.2.1 and 5.3.1.

13. Precision and Bias

13.1 *Multi-Laboratory Precision:*

13.1.1 *Average Expansion Less Than 0.014 %*—The multi-laboratory standard deviation of a single test result (mean of measurements of three prisms) for average expansion less than 0.014 % has been found to be 0.0032 % (CSA A23.2-14A-M90).[5] Therefore, results of two properly conducted tests in different laboratories on the same aggregate should not differ by more than 0.009 %, nineteen times out of twenty.

13.1.2 *Average Expansion Greater Than 0.014 %*—The multi-laboratory coefficient of variation of a single test result (mean of measurements of three prisms) for average expansion greater than 0.014 % has been found to be 23 % (CSA A23.2-14A-M90).[5] Therefore, results of two properly conducted tests in different laboratories on the same aggregate should not differ from each other by more than 65 % of their average, nineteen times out of twenty.

13.2 *Range for Three Prisms:*

13.2.1 *Average Expansion Less Than 0.02 %*—For average expansions of less than 0.02 %, the multi-specimen, single operator standard deviation has been found to be 0.0025 % (CSA A23.2-14A-M90). Therefore, the range (difference between highest and lowest) of the three individual prism measurements used in calculating an average test result should not exceed 0.008 %, nineteen times out of twenty.

13.2.2 *Average Expansion Greater Than 0.02 %*—For average expansions of more than 0.02 %, the multi-specimen, single operator coefficient of variation has been found to be 12 % (CSA A23.2-14A-M90). Therefore, the range (difference between highest and lowest) of the three individual prism measurements used in calculating an average test result should not exceed 40 % of the average, nineteen times out of twenty.

13.3 *Bias*—Nothing is being said concerning the bias.

14. Keywords

14.1 aggregate; alkali-silica reactivity; concrete; length change

APPENDIX

(13)

(Nonmandatory Information)

X1. Interpretation of Results

X1.1 The question of whether or not criteria based on the results obtained using this test method should be used for acceptance of materials for use as concrete aggregate will be dealt with, if deemed appropriate, in Specification C 33.

X1.2 Work has been reported from which it may be inferred that an aggregate might reasonably be classified as potentially deleteriously reactive if the average expansion of three concrete specimens is equal to or greater than 0.04 % at one year (7) (CSA A23.1-M90 Appendix B, Table 3.1).

X1.3 A history of satisfactory field performance in concrete is the best method of evaluating the potential for an aggregate to cause premature deterioration of concrete due to alkali-silica reaction. When field performance of an aggregate in concrete is to be accepted, the following conditions should be met (8):

X1.3.1 The cement content and alkali content of the cement should be the same or higher in the field concrete than is proposed in the new structure.

X1.3.2 The concrete examined should be at least 10 years old.

X1.3.3 The exposure conditions of the field concrete should be at least as severe as those in the proposed structure.

X1.4 This test method supplements the results of other test methods. The results of the other test methods are usually reported before the results of this test method are available. Standards that this test method supplements include: Test Method C 227, Guide C 295, Test Method C 289, and Test Method C 1260. It is recommended that the relevant procedure(s) be performed concurrently with this test method and any discrepancies between the results explained. Care should be exercised in the interpretation of these other test method results (9, 10, 11, 12, 13, 14).

X1.5 The use of this test method should especially be considered when other test methods may be inadequate. Some examples of such problems are as follows: The potential reactivity of various varieties of quartz may not be accurately determined by Test Method C 227 since the test method may produce a false-negative result (3). False-negative results are possible with a number of aggregates such as slow-late expanding argillaceous greywackes, strained quartz and microcrystalline quartz associated with strained quartz (3, 4, 13). False-negative results are also possible due to storage conditions (9), reactive aggregate levels far above or below pessimum (3) or insufficient alkali to accelerate the test (3). The potential reactivity of various varieties of quartz may not be accurately determined by Test Method C 1260 since the test method may produce a false-positive result with a number of marginally reactive aggregates (13). Test Method C 1260 may also give a false-negative result with aggregates suspected of containing deleterious strained quartz (14).

X1.6 If the data generated with other test methods and supplemented with information from this test method judge an aggregate to be "not potentially deleteriously alkali-silica reactive," no restrictions are usually required with the use of that aggregate in order to protect against expansion due to alkali-silica reaction (7) (see Note X1.1).

NOTE X1.1—In critical structures such as those used for nuclear containment or large dams, where slight expansions cannot be tolerated, a lower expansion limit may be required.

REFERENCES

(1) Diamond, S., "Alkali Reactions in Concrete-Pore Solution Effects," *Proceedings*, 6th International Conference on Alkali-Aggregate Reaction in Concrete, Copenhagen, Denmark, 1983, pp. 155–166.

(2) Diamond, S., "ASR—Another Look at Mechanisms," *Proceedings*, 8th International Conference on Alkali-Aggregate Reaction, Kyoto, Japan, 1989, pp. 83–94.

(3) Grattan-Bellew, P. E., "Test Methods and Criteria for Evaluating the Potential Reactivity of Aggregates," *Proceedings*, 8th International Conference on Alkali-Aggregate Reaction, Kyoto, Japan, 1989, pp. 279–294.

(4) Grattan-Bellew, P. E., "Microcrystalline Quartz, Undulatory Extinction and Alkali-Silica Reaction," *Proceedings*, 9th International Conference on Alkali-Aggregate Reaction in Concrete, Concrete Society, Slough, U.K., 1992, pp. 383–394.

(5) Rogers, C. A., and Hooton, R. D., "Comparison Between Laboratory and Field Expansion of Alkali-Carbonate Reactive Concrete," *Proceedings*, 9th International Conference on Alkali-Aggregate Reaction in Concrete, Concrete Society, Slough, U.K., 1992, pp. 877–884.

(6) Rogers, C. A., "General Information on Standard Alkali-Reactive Aggregates from Ontario, Canada," Ontario Ministry of Transportation, Engineering Materials Office, 1988, p. 59.

(7) Grattan-Bellew, P. E., "Reevaluation of Standard Mortar Bar and Concrete Prism Tests," *Materiaux et Constructions*, Vol 16, No. 94, 1983, pp. 243–250.

(8) British Cement Association, "The Diagnosis of Alkali-silica Reaction," British Cement Association, Crowthorne, Berks, RG1 6YS, United Kingdom, Second edition, 1992.

(9) Rogers, C. A., and Hooton, R. D., "Reduction in Mortar and Concrete Expansion with Reactive Aggregates Due to Leaching," *Cement, Concrete and Aggregates*, CCAGDP, Vol 13, 1991, pp. 42–49.

(10) Bérubé, M. A., and Fournier, B., "Accelerated Test Methods for Alkali-Aggregate Reactivity," *Advances in Concrete Technology*, Malhotra, V. M., ed., Canada Communication Group, Ottawa, 1992, pp. 583–627.

(11) Sorrentino, D., Clément, J. Y., and Goldberg, J. M., "A New Approach to Characterize the Chemical Reactivity of the Aggregates," *Proceedings*, 9th International Conference on Alkali-Aggregate Reaction in Concrete, Concrete Society, Slough, U.K., 1992, pp. 1009–1016.

(12) Fournier, B., and Bérubé, M. A., "Application of the NBRI Accelerated Mortar Bar Test to Siliceous Carbonate Aggregates

Produced in the St. Lawrence Lowlands (Quebec, Canada), Part I: Influence of Various Parameters on the Test Results, *Cement and Concrete Research*, Vol 21, 1991, pp. 853–862.

(13) Hooton, R. D., "New Aggregate Alkali-Reactivity Test Methods," Ontario Ministry of Transportation, Research and Development Branch Report MAT-91-14, November, 1991.

(14) Kerrick, D. M., and Hooton, R. D., "ASR of Concrete Aggregate Quarried from a Fault Zone: Results and Petrographic Interpretation of Accelerated Mortar Bar Test," *Cement and Concrete Research*, Vol 22, 1992, pp. 949–960.